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IMPROVED TRAJECTORY CALCULATIONS FOR HELICOPTER-LAUNCHED MISSIL--ETC(U)
JUL 79 J L HESS, R W CLARK DAAG29-76-C-0021
UNCLASSIFIED MDC-J8550 ARO-13690.1-EX NL

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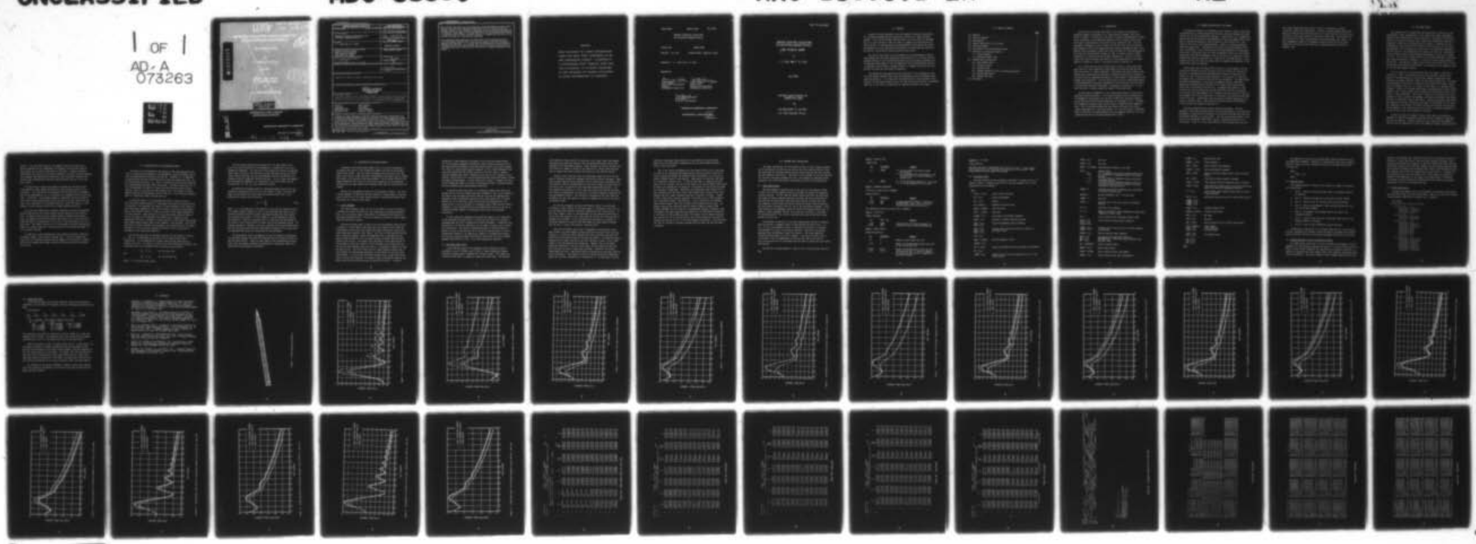

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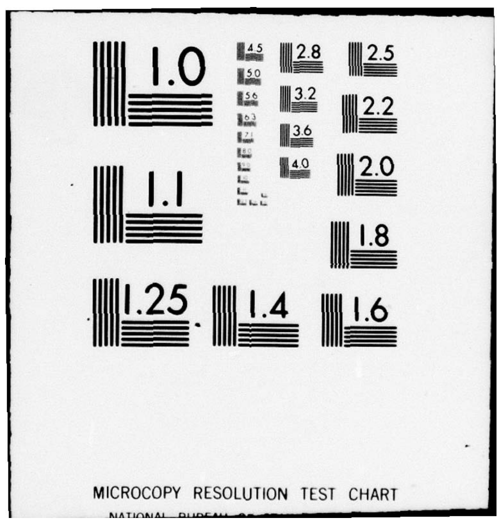
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A method has been developed to provide improved trajectory calculations for helicopter-launched missiles based on an earlier U.S. Army trajectory program. In the earlier method the helicopter rotor flow field is simulated but, at a given instant of time, the flow is assumed to be uniform over the whole missile. By incorporating a three-dimensional panel method the forces and moments due to the flow-field nonuniformity are calculated and applied in the form of a perturbation about the uniform flow values. over

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The uniform flow values can be estimated by using experimental results incorporated into the basic trajectory calculation and so in this way the predominant effects of the flow-field separation can be accurately accounted for. A relatively crude model of the flow separation for the perturbation solution is therefore used in which a blowing velocity is imposed over the part of the missile for which the flow would be separated.

This method has been applied to the calculation of the trajectory of the 2.75-Inch Rocket launched from a hovering helicopter using two different downwash distributions. It is found that the modification to the trajectory introduced by the calculated effects due to the flow-field nonuniformity is relatively small but it can still be significant as regards accuracy at the target.

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Prepared by: J. L. Hess and R. W. Clark

Approved by:

Tuncer Cebeci
Chief Technology Engineer
Research
Aerodynamics Subdivision

R. B. Harris, for
Frank T. Lynch
Branch Chief
Research and Development
Aerodynamics Subdivision

R. B. Harris
R. B. Harris
Director — Aerodynamics

DOUGLAS AIRCRAFT COMPANY

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IMPROVED TRAJECTORY CALCULATIONS FOR HELICOPTER-LAUNCHED MISSILES

FINAL TECHNICAL REPORT

Feb 76 - Jul 79

BY

J. L. HESS AND R. W. CLARK

JULY 1979

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FOR

THE DEPARTMENT OF THE ARMY

U.S. ARMY RESEARCH OFFICE

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1.0 ABSTRACT

A method has been developed to provide improved trajectory calculations for helicopter-launched missiles based on an earlier U.S. Army trajectory program. In the earlier method the helicopter rotor flow field is simulated but, at a given instant of time, the flow is assumed to be uniform over the whole missile. By incorporating a three-dimensional panel method the forces and moments due to the flow-field nonuniformity are calculated and applied in the form of a perturbation about the uniform flow values.

The uniform flow values can be estimated by using experimental results incorporated into the basic trajectory calculation and so in this way the predominant effects of the flow-field separation can be accurately accounted for. A relatively crude model of the flow separation for the perturbation solution is therefore used in which a blowing velocity is imposed over the part of the missile for which the flow would be separated.

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3.0 INTRODUCTION

The basic aim of the work described in this report is to obtain an improved trajectory calculation for a finned missile launched from a helicopter in flight. In particular, the study is aimed at determining the effect on the trajectory of the nonuniform character of the velocity field of the rotor that is experienced by the missile at any instant of time. Existing procedures (references 1 and 2) account for the fact that the flow environment changes as the missile advances radially outward through the rotor field. However, these procedures assume either that the velocity field experienced by the missile at any particular instant of time is uniform or that a simple correction to a uniform flow can be made (reference 2). The basic calculational tool used to evaluate the effects of flow nonuniformity is the panel method of reference 3, which is described briefly in Section 5.0.

It is clear that during the launch phase a missile in the strong downwash field of a rotor experiences large angles of attack and that the flow about the missile is largely separated. Accordingly, the early stages of the present work concentrated on developing a potential-flow model of separated flow that could be implemented by means of a panel method. Unfortunately, the attempt was unsuccessful. This was partly due to the very complicated nature of three-dimensional separation (reference 4) and partly due to uncertainties of constructing potential-flow models of separation (reference 5). In any event the task is clearly beyond the scope of the present work.

An additional consideration is the rather good accuracy of the results obtained by existing methods. In the near-to-medium future no method based on fundamental flow analysis will be able to match the accuracies obtained by the more practically-oriented techniques of references 1 and 2. Moreover, the fundamental procedure would require orders of magnitude more computing time. Once it had been decided that the present work would be directed towards development of a practical method, i.e., one that offers a reasonable hope of improving on existing methods with an acceptable computing time, the permissible outline of the method became fairly clear.

4.0 GENERAL DESCRIPTION OF THE METHOD

The essential property of the method of this report is that it calculates a perturbation to a uniform onset-flow solution, which thus becomes the total solution as the flow nonuniformity vanishes. Specifically, it is assumed that tabular data exists that permit determination of force and moment coefficients due to a uniform freestream at any inclination to the missile axis. The source of this data is not considered here. Ideally, it would be gathered from wind tunnel tests. The method also relies on existing programs of the type of references 1 and 2, which not only provide machinery for integrating the missile's trajectory given its force and moment history, but also contain subroutines that give the downwash field of the rotor as a function of radial location and relative blade position. Essentially, the panel method is incorporated into this last type of program where it computes perturbations to the uniform-flow forces and moments.

At any given time the known missile position is used together with the rotor-field subroutine to give the onset flow at all points of the missile. One point is selected where the magnitude and direction of the onset flow velocity is felt to be particularly important. This velocity is used with the tabular data to obtain uniform-flow forces and moments. The panel method calculates perturbations to the forces and moments based on differences between the nonuniform onset flow due to the rotor and the above uniform onset flow, as described in Section 6.0. A somewhat open question is the selection of the point where the uniform onset-flow velocity is evaluated. For a missile with rear-mounted fins, it appears that the principal effect of the downwash field on the flight path is the pitch up resulting from the down force on the fins. Accordingly, the fin location has been selected as this velocity reference point. Some calculated results showing the importance of this choice are presented in Section 7.0.

The above formulation has several important advantages. The most important is that the principal effects of the calculationally very difficult phenomenum of separation are contained in the uniform-flow solution, which can be obtained routinely in a wind tunnel. Thus the calculational effort is confined to the nonuniform field effect, which is beyond the capability of a wind tunnel. Since it is only a perturbation, the calculated flow can use a very simple separation model, similar to that of reference 6, without introducing significant inaccuracies. Finally, the panel-method calculation need be carried out only while the missile is in the field of the rotor, which represents a very small fraction of the total flight time. Once the missile has left the rotor field the trajectory calculation becomes very simple. A more fundamental attempt at flow modelling would require use of the panel method over the entire flight path with a consequent massive increase in computer time.

5.0 THE PANEL METHOD

The evaluation of the nonuniform-flow-field effects involves only the calculation of small perturbations to the uniform-flow forces and moments induced by the nonuniform part of the flow field. As stated in the previous section, the velocity reference point at which the uniform-flow velocity is evaluated is taken to be at the missile fin location. Therefore, the nonuniform part of the flow field will vanish at this point and so, to a good approximation, the flow about the missile due to the nonuniform component of the flow field will be unaffected by the presence of the fins. Accordingly, it was decided to apply the panel-method calculation to the missile without its fins. This, in turn, permits the use of the three-dimensional nonlifting panel method described in reference 3, since no lifting surfaces remain on the missile. This method is simpler, more flexible and faster than a lifting method whose use would add significantly to the complexity and computing time of the resulting computer program.

For full details of the panel method used, the reader is referred to reference 7. Only a brief description will be given here, together with details of the modifications to the existing computer program which were necessary to produce a method suitable for the current application. The model used represents the missile by a number of flat quadrilateral panels, mostly nearly rectangular (see fig. 1), on each of which there is a constant source strength. A matrix of influence coefficients, representing the normal velocity induced on all of these panels by the singularity distribution on each of the panels, is then calculated. This matrix is then used to determine the source strengths in such a way that the boundary condition of prescribed total normal velocity is satisfied on each of the panels. Additional matrices representing the tangential velocities induced by each panel are calculated so that, given the singularity distribution, the entire velocity distribution over the body can be computed. This calculation can be carried out routinely regardless of the nature of the flow field incident to the body.

In order to reduce the number of panels which need to be considered, advantage is taken of the symmetry about the vertical lengthwise plane which the missile possesses. (Clearly the missile has a good deal more symmetry than this but the complexity of using this symmetry increases rapidly with the degree.) The flow field itself is not symmetric about this plane but it can be separated into two components, one symmetric and the other antisymmetric whose sum is equal to the physical flow field. Separate influence coefficients are required for these two components, but their solution requires less computer time than would be required to solve one matrix equation with twice as many unknowns, which would be required without the use of this symmetry option.

The calculation of the missile behavior through the helicopter rotor field requires a panel method calculation at each successive point of the trajectory. Since the normal and tangential velocity matrices are dependent only on the body geometry, it is not necessary to recompute them for each time step. In addition, a considerable amount of computing time can be saved by storing the inverse normal velocity matrices for use at each successive time step. Thus, the amount of calculation required at each time step is a small fraction of that required for the initial panel method calculation.

The basic panel method was, therefore, modified to permit the tangential velocity matrices and the inverse normal velocity matrices to be stored on disk. By greatly restricting the maximum number of panels which could be used, as compared with the basic method, (see Section 7.0) it was possible to enable one entire influence matrix to be held in the high-speed core at any given time. This permits the use of an in-core matrix solution routine which leads to a further reduction in the computing time by reducing the number of disk transfers required.

In addition to these modifications, the program was further simplified to remove a number of the external storage units. The basic program used these units for transferring data from one segment of the program to another, but with the reduced panel number used here, these data can now be retained in the core.

6.0 CALCULATION OF THE PERTURBATION FORCES

As stated in the Introduction, the purpose of the panel-method calculation is to provide perturbations to the aerodynamic forces and moments due to the flow nonuniformities acting on the missile. Therefore, it is necessary to calculate the pressure distribution due to both the total onset flow, $\vec{u}_T$, and the uniform onset flow, $\vec{u}_o$, which is defined by evaluating the velocity at a predetermined reference point on the body. Typically, the missile is in the rotor downwash for about 0.1 seconds and the principal effect of this velocity field on a missile with rear mounted fins is to induce a pitching moment caused by the aerodynamic forces on the fins. This velocity reference point is, therefore, taken to be near the tail.

A simplified model of the separated-flow effect is used in which a positive normal blowing velocity is introduced over panels for which the flow is separated. The separated-flow region is simply defined by that region for which the normal component of the onset velocity is positive, and the magnitude of the blowing velocity is taken to be equal to the normal component of the onset velocity. When defined in this way the blowing velocity tends to zero at the edges of the separated-flow region and, if applied to two-dimensional flow past a cylinder, it would result in a wake behind the cylinder whose downstream thickness tends to the diameter of the cylinder. The precise definition of these separated flow parameters can be modified, but the results presented in the next section indicate that there is not a great deal of dependence on the separation modelling.

Two blowing velocities are therefore defined for each panel of the body, b_T and b_o, corresponding to the total and the uniform onset flows, respectively. In the attached-flow regions these blowing velocities are defined to be zero. To achieve a solution with these blowing distributions, the right-hand sides for the normal velocity equations are defined by

$$-\vec{u}_T \cdot \hat{n} + b_T \qquad \text{for the total flow}$$

and (6.1)

$$-\vec{u}_o \cdot \hat{n} + b_o \qquad \text{for the uniform flow}$$

where $\hat{n}$ is the unit normal vector.

The two vectors defined by evaluating (6.1) for each panel on the missile are each separated into two components, a symmetrical and an anti-symmetrical component. The respective source densities required to generate these normal velocities over the body are then calculated using the inverse normal velocity matrices and the corresponding velocity distributions are computed using the tangential velocity matrices. At this stage the symmetric and antisymmetric components are recombined to give the surface velocity distributions $\vec{v}_T$ and $\vec{v}_o$ over the entire missile.

By making the assumption that the freestream dynamic pressure for any streamline impinging on the missile at any instant of time is constant and equal to the uniform-flow value, then the pressure coefficient in the attached flow region can be written as

$$c_p = 1 - \frac{v^2}{v_o^2} \tag{6.2}$$

where v_o is the magnitude of the velocity at the velocity reference point. This formula cannot, however, be used in the separated-flow region since an artificial blowing velocity has been introduced to model the flow outside the separated-flow region. In this region, at a given lengthwise station, the pressure is taken to be constant with its value given by the average of the values at the control points on either side of the separated region. The computer program is, therefore, set up to calculate the pressure coefficients for both the uniform and the total flows based on equation (6.2) after which the separated-flow values are overwritten as outlined above.

The perturbation forces and moments are then calculated by integrating the difference between the total-flow pressure and the uniform-flow pressure over the whole missile. These are then added to the corresponding uniform-flow forces and moments (obtained experimentally or otherwise) before proceeding with the trajectory calculation.

7.0 DISCUSSION OF CALCULATED RESULTS

A measure of the normal-plane impact error in a missile trajectory is provided by the errors in the flight-path angle at the end of the boosted stage of the flight. Thus the results presented here cover only this segment of the missile flight with both instantaneous pitch angle and the flight-path angle in the vertical plane being plotted. The principal effect of the imposed downwash field occurs in the vertical plane and so the horizontal deviation has not been plotted here although these data are calculated by the program.

Results for two downwash fields will be presented in detail: the first a linear downwash in which the vertical velocity is proportional to the distance from the axis of the rotor and the second a simulated helicopter rotor field based on a helical vortex model.

7.1 Linear Downwash

The linear downwash, which is zero on the rotor axis and 116 ft/sec at a distance of 20 feet from the axis, was considered by Figueras and Bauman (ref. 1) in an earlier study of the effect of a downwash distribution on a helicopter-launched missile. This case, therefore, provides a useful comparison with the earlier results.

The missile-launch point is taken to be on the helicopter centerline at a distance of 3 feet ahead of the rotor axis, and figures 2 and 3 show the instantaneous missile pitch and flight-path angle respectively, where three curves have been plotted in each figure. The first is that obtained from the basic trajectory program in which the downwash field is evaluated at the missile center of gravity and is assumed to apply uniformly over the whole length of the missile. The second curve represents a minor modification to this program in which the velocity is still assumed to be uniform over the missile, but the reference point at which it is evaluated is taken to be near the missile tail. The third curve uses this same reference velocity but it also includes the panel-method evaluation of the effects of the flow field nonuniformity. It can be seen from these figures that a significant correction in the missile trajectory is achieved simply by moving the velocity reference point from the missile center of gravity to the tail. A further correction is then achieved by allowing for the flow-field nonuniformity. For this particular downwash distribution, both of these corrections act in the same direction producing a nose-down pitch relative to the basic method. This result is clearly what would be expected for this simple downwash field since the evaluation of the uniform velocity at the tail gives a reduced vertical component and hence a reduced pitch up due to the influence of this velocity on the missile fin, and the nonuniform flow effect contributes further nose-down pitching moment. A total correction of about 1.3 degrees (22 mils) in the flight-path angle at the end of the boosted flight is obtained between the basic method and the panel-method calculation.

It should be noted that there is a difference between the results presented here for the basic method and those presented in fig. 10 of reference 1. The results have the same qualitative behavior but both the magnitude and frequency of the oscillations occurring in the pitch angle (fig. 2) differ. Despite, as far as possible, using the same missile characteristics and launch point, it was not possible to reproduce exactly these earlier results. Therefore, it was concluded that this discrepancy must be due to the use of slightly different dynamic or aerodynamic data within the trajectory calculation.

For this particular downwash the calculation appears to be insensitive to the separated-flow model which is used since the results are virtually unchanged when the flow is assumed to be totally attached. In addition, the calculation is relatively insensitive to the number of panels used to represent the missile. The results presented here were all obtained using 60 panels over half of the missile, 10 in the axial direction and 6 in the circumferential direction. By doubling the number of circumferential panels, but using the same axial-panel distribution, the results for the triangular downwash distribution of figs. 2 and 3 were graphically identical.

7.2 Helicopter Rotor Field

A more realistic model of the downwash below a helicopter rotor is provided by a set of routines used in the U.S. Army 6-degree-of-freedom trajectory program used to simulate the 2.75-inch rocket. This model uses a helical vortex which is assumed to leave each rotor blade. The location and strength of these vortices is given by a set of data, while the program calculates the resulting velocity field including modifications due to the presence of the helicopter fuselage. These routines are used to evaluate the flow field at a number of points on the missile axis, these values are then used to compute the normal velocity distribution on the missile surface.

Figures 4 and 5 show the pitch and flight-path angle for the 2.75-inch missile launched through this downwash field with no initial incidence. Again these figures show the curves obtained for the uniform-flow calculations with the reference velocity evaluated both at the missile center of gravity and at the missile tail in addition to the nonuniform panel-method solution. For this downwash distribution it can be seen that moving the velocity reference point alone overcompensates for the error in the basic method as compared with the panel-method solution. The correction introduced by the flow-field non-uniformity for this case amounts to about 0.5 degrees or 9 mils at the end of the boosted flight.

As with the triangular velocity distribution, there is no noticable difference in these figures if the panel number is increased to 120 and so it was concluded that 60 panels provide an adequate missile representation. In this case, however, there is some dependence on the separation algorithm as can be seen from figures 6 and 7 which show the results for which the flow is assumed to be attached. In this attached flow case there is virtually no difference between the results with and without the panel method provided that the tail is used as the velocity reference point.

Since the helicopter rotor field is dependent on the position of the rotor blades, the panel method has been applied with various rotor positions. Figures 8 - 11 show the results obtained for rotor positions varying by 45^{o} and 90^{o} from the position used for the previous results. For these particular combinations of launch conditions and rotor positions, there is only a small change in the calculated missile trajectory. However, due to the highly nonuniform character of the flow field, there could be cases for which the rotor position can have a significant influence. Similarly, the initial launch-angle can have a significant effect on which part of the flow field the missile encounters. Two figures, 12 and 13, plot the pitch and flight-path angles for a missile launched at an incidence of 7^{o}. In this case it can be seen that a nose-down pitch correction is provided by the panel method whereas for the horizontally launched missile the panel method provides a nose-up pitch correction.

All of the results presented so far have been derived using a time step of 0.025 in the trajectory calculation which, while providing a useful qualitative comparison between the different cases and methods, is too large to permit reliable results to be obtained. Some results for smaller time steps are presented in figures 14-17. It can be seen that, by reducing the time step to 0.0125 seconds, both the initial peak in the nose-up pitch, which occurs at about 0.27 seconds, and the subsequent oscillations in the missile attitude are increased in magnitude. Similarly, the flight-path angle (figure 15) is also increased over the whole flight time plotted here for each of the three methods with the largest increase occurring in the basic solution. Figures 16 and 17 show that a further reduction in the step size to 0.005 produces a less significant change in the solution. It can, therefore, be concluded that for most cases a time step of about 0.0125 seconds could be used. For greater accuracy the time step could be further reduced to about 0.005 seconds although this will lead to a corresponding increase in computer time. For example, the total computing time required on an IBM 370/3033 system for a time step of 0.005 seconds was about 100 seconds of which about 60 seconds was required for all of the helicopter rotor field evaluations and about 30 seconds was required for all of the panel-method calculations. The corresponding time for the basic trajectory program with the same time step was about 10 seconds.

8.0 PROGRAM INPUT INSTRUCTIONS

The input instructions for the modified version of the trajectory program can be conveniently divided into two parts, the first providing control flags and input data for the panel method and the second providing the data required for the trajectory calculation. The latter is very similar to the data required for the basic trajectory program with only a few changes and additions being necessary, but a brief description of both data sets will be provided here.

8.1 Panel Method Input

The panel method is executed once at the start of the program in order to read in the missile geometry data and calculate the normal and tangential velocity matrices. At this time the normal velocity matrices are factorized into upper and lower triangular matrices to permit the rapid calculation of the solutions for additional right-hand sides required for each time step. The tangential velocity matrices and the factorized normal velocity matrices are then stored on external units for use as the calculation proceeds. Since these quantities are dependent solely on the missile panelling which will, in general, remain unchanged from one run to the next, an option is provided for bypassing much of this initial calculation by using the matrices stored during a previous run.

As mentioned in Section 5.0, the panel method makes the basic assumption that the missile is symmetric about a plane through the missile axis. In fact, as far as the geometric input is concerned, the missile is assumed to be axisymmetric so that, if the missile profile is specified, the program generates the circumferential panel distribution. The array dimensions currently defined allow for up to 10 panels in the axial direction with up to 18 panels in the circumferential direction, over half of the missile. Thus up to eleven pairs of coordinates must be input to define the axial panel distribution.

The data for the panel method is input on unit 5 and the cards required are:

Card 1 — Control Card

Format (2I2)

cc	Variables	Remarks
1-2	MODE1	=0 for an initial run with new panel distribution
		=1 for subsequent runs using geometry data stored on units 8, 9 and 13 during a previous run
3-4	MODE2	=0 if the helicopter downwash is to be used
		=1 if a linear downwash is to be used

Card 2 - Downwash Parameters

This card in input only if MODE2≠0

Format (2F10.6)

cc	Variables	Remarks
1-10	DN1	A linear downwash velocity is defined by
11-20	DN2	DN1+DN2*DDISS where DDISS is the horizontal distance from the rotor axis

The remaining cards must be input only if MODE1=0.

Card 3 - Title Card

Format (15A4,A4)

cc	Variables	Remarks
1-60	HEDR	Alpha-numeric title and case number for
61-64	KASE	printing at head of panel method output

Card 4 - Input Control

Format (2I5,2F10.5)

cc	Variables	Remarks
1-5	N	Number of axial panels ($N \leq 10$)
6-10	M	Number of circumferential panels over half of the missile ($M \leq 18$)
11-20	B=1.0	Length of axes defining elliptic missile
21-30	C=-1.0	cross-section (N.B. C must be negative to ensure that the missile is panelled in the correct order.)

Cards 5-7 - X-Z Input

Format (6F10.0)

The input consists of coordinate pairs (X_1, Z_1, X_2, Z_2, ..., X_{N+1}, Z_{N+1}) defining the profile of the body to be generated by the program. These points define the axial panel distribution.

8.2 Trajectory Input

The data required for the trajectory calculation is input on unit 3 in Namelist Format. A sample input list will be given together with a brief explanation of the variables:

&PUTT

ALTIN = -100.0,	Initial launch altitude
CKO = 0.0,	Thrust misalignment
CK1 = 0.0,	Vectors
CK4 = 6360.0,	Related to missile thrust
DELØ2 = 0.00625,	Half time step
DELTT = 0.0125,	Time step
DIVANG = 0.0,	Dive angle of helicopter (degrees)
DNSCH = 0.5,	Constant in dynamic pressure equation
DPIT = 0.0, DYAW = 0.0,	Thrust misalignment angles (radians)
DXLN = 3.0, DYLN = 0.0, DZLN = 7.0,	Missile launch position relative to center of helicopter rotor
DZZ = 0.0,	
D2RFF = 0.2292,	Missile diameter in feet
FACTØR = 0.0,	
FAC = -6.56,	Used to calculate trim pitch attitude of helicopter
FG = 0.0,	
FTØRM = 0.0,	Specifies units (0.0 for English units or 1.0 for metric units)

GAIN1 = 0.0,	Not used
GAIN2 = 0.0,	Not used
GREFF = 32.173996,	Gravitational constant at sea level
HELIC	Control flag:
= 0.0,	for no downwash (and no panel method calculation)
= 1.0,	for calculation of downwash effects using panel methods
= -1.0,	for calculation of downwash effects using basic trajectory program
= 2.0,	for calculation of downwash effects using basic trajectory program but with reference velocity evaluated at the missile tail
INPRØ = 0,	Indicates that missile reference axes correspond to missile principal axes
INPUTØ = 1,	Restart parameter, set = 1 for new case
INTØPT = 1,	Not used
ITUMB = 1,	Specifies axes fixed with respect to rotating missile
JET = 0,	Specifies no jet damping
N = 25,	Number of variables to be integrated by Runge-Kutta integration (leave fixed)
NN = 1,	First variable to be integrated (leave fixed)
PHIZD = 0.0, PSIZD = 0.0, THTZD = 0.0,	Initial missile launch angles (degrees)
PITMAL = 0.0, YAWMAL = 0.0,	Pitch and yaw tip rates as missile leaves launcher (radians/sec)
QELNCH = 0.0,	Missile launcher angle (degrees)
RAMP = 0.0, WCF = 0.0, WDF = 0.0,	Horizontal wind components defined by WCF+RAMP*TIME in the cross-range direction and WDF down range
REF = 20902704.0	Radius of earth (feet)
RØTRAD = 22.0	Rotor radius (feet)
SCARF = 0.00219	Used to define missile spin moment
SPNRAT = 0.0	Initial missile spin rate (radians/sec)

SUSØN = 0.0	Booster motor burn
SUSØFF = 1.551	Times (seconds)
TIME = 0.092,	Missile launch time (seconds)
TFINAL = 1.592,	End of calculation (seconds)
TRØT = 0.092,	Used to vary rotor blade phase at time of missile launch
TLL = 0.092,	Time missile leaves launcher (seconds)
TPRINT = 0.025,	Time interval at which trajectory data is printed
TPLØT = 0.025,	Time interval at which missile pitch and flight path angles are stored for subsequent plotting
T1 = 0.22,	Time at which panel method calculations are discontinued (seconds)
VINIT = 0.0,	Helicopter velocity at missile launch time (ft/sec)
XINDØT = 0.0, YINDØT = 0.0, ZINDØT = 0.0,	
XLENG = 4.4,	Launcher length (feet)
XMASSO = 0.61727,	Initial missile mass
XMAX = 0.0,	Not used
XMIN = 0.0,	Not used
XMV = 109.0,	Missile velocity out of launch tube (ft/sec)
XTAR = 13000.0, YTAR = 0.0, ZTAR = 0.0,	Target range, cross-range and altitude (feet)
YJET = 0.0, ZJET = 0.0,	Jet damping terms
ZLL = 0.0, ZLM = 0.0, ZLN = 0.0,	

&END

On completion of one case the program begins another calculation with the same missile geometry. Execution is terminated by specifying a negative value for TIME, and so the following cards must be included on the end of this data set.

```
&PUTT
    TIME = -1.0,
&END
```

8.3 External Units

This program requires 7 external units whose unit numbers and contents are listed below:

1. Unit 2: Used for storing trajectory data for subsequent analysis or plotting.
2. Unit 4: Temporary storage unit used within the panel method.
3. Unit 8: Used to store the inverse normal velocity matrices.
4. Unit 9: Used to store geometric data calculated during the first call to the panel method.
5. Unit 10: Helicopter rotor downwash data to be input to the trajectory program.
6. Unit 11: Used to store pitch and flight-path angle data for subsequent analysis or plotting.
7. Unit 13: Used to store tangential velocity matrices.

As mentioned in subsection 8.1, the output from units 8, 9 and 13 can be used for subsequent runs thereby avoiding the need to recompute the influence matrices and their inverses if they remain unchanged from one run to the next.

8.4 Changes Necessary to Run an Alternative Missile

The panel-method calculation is set up to handle any axisymmetric missile geometry, but the trajectory program with which it is linked is based on the U.S. Army 2.75-inch rocket. Therefore, for application to alternative missiles, in addition to modifying the input geometry data, the trajectory calculation would need to be modified. There are a number of minor changes required within this section of the program; for instance the position of the center of gravity is defined as a linear function of time and so the constants involved in this expression would need to be changed. In addition, there may be other implicit assumptions involved within the code. However, the main change necessary would be to replace the dynamic and aerodynamic data tables at the beginning of the Main program with coefficients appropriate to a new missile. It should also be pointed out that, since the program still relies heavily on these data tables for the computation of the steady flow effects, improved trajectory calculations could be achieved by replacing these data tables with improved wind-tunnel results as they become available.

8.5 Overlay Description

To reduce the computer core size requirement this program is designed to run using the overlay structure defined below. When run in this way, a region of approximately 300K bytes of computer core is required.

Card Column

```
12345678901234567890
   OVERLAY L1
     INSERT INPUT
     INSERT HEADER
     INSERT LDAY
   OVERLAY L1
     INSERT VFORM
     INSERT AWRTE
   OVERLAY L1
     INSERT COEF
     INSERT QUASI2
     INSERT SEPCP
     INSERT BCS
     INSERT BC
     INSERT BN
     INSERT NS
   OVERLAY L1
     INSERT FUSLGE
     INSERT HELVEL
     INSERT VLCTY
     INSERT TABLK
     INSERT TABL2
     INSERT MULTY
     INSERT INVERT
```

8.6 Program Test Case

A test case has been run using the trajectory input data described in subsection 8.2 (with HELIC=1.0) together with the following panel method input data:

(Card Column)

```
              1         2         3         4         5         6
1234.....0123......0123......0123......0123......0123......012345
 0 0
   10 X  6 MISSILE - ONE PLANE OF SYMMETRY TEST CASE          2
   10    6        1.0      -1.0
        4.5       0.0    4.1625 0.0572915    3.8250 0.114583
      3.425  0.114583       2.9  0.114583       2.4 0.114583
        1.8  0.114583       1.2  0.114583       0.6 0.114583
        0.2  0.114583       0.0  0.114583
```

This represents a 60 panel test case with a missile length of 4.5 feet and diameter of 2.75 inches. For production runs, the precise missile geometry corresponding to the 2.75 inch Rocket would need to be substituted.

Some of the output is given in figures 18(a) and (b). Figure 18(a) lists the output produced by the panel method consisting of the geometric data defining the coordinates of the panel corners together with the components of the unit normal vectors for each panel. The values NPX, NPY and NPZ define the control point coordinates for each panel while the final column lists some other geometric properties of the panels including their area which are used during the formation of the velocity matrices within the panel method.

The remainder of the output represents a sample of the output produced during the trajectory calculation, of which the first page and the last two pages have been included.

9.0 REFERENCES

1. Figueras, D. and Bauman, R.: Downwash Effects on Rocket Trajectories. Electronic and Space Division, Emerson Electric Co., St. Louis, Mo. (Presented at a Technical Conference on "The Effects of Helicopter Downwash on Free Projectiles" held at U.S. Army Aviation Systems Command, St. Louis, Mo., 12-14 August 1975.)

2. Wasserman, S. and Yeller, R.: Preliminary Analysis of the Effect of Calculated Downwash Distributions on the Flight Performance of the 2.75-inch Rocket. Picatinny Arsenal, Dover, New Jersey. (Presented at a Technical Conference on "The Effects of Helicopter Downwash on Free Projectiles" held at U.S. Army Aviation Systems Command, St. Louis, Mo., 12-14 August 1975.)

3. Hess, J.L. and Smith, A.M.O.: Calculation of Nonlifting Potential Flow About Arbitrary Three-Dimensional Bodies. J. of Ship Research, Vol. 8, No. 2,22, Sept. 1964. (A somewhat expanded version is contained in Douglas Aircraft Co. Rept. No. ES 40622, March 1962.)

4. Wang, K.C.: Separation of Three-Dimensional Flow. Martin Marietta Labs. Rept. MML TR-76-54C, Aug. 1976. (U.S. Dept. of Commerce National Technical Information Service, AD-A033569.)

5. Dvorak, F.A., Maskew, B. and Woodward, F.A.: Investigation of Three-Dimensional Flow Separation on Fuselage Configurations. Analytical Methods, Inc. Rept. USA AMRDL-TR-77-4, Mar. 1977.

6. Woodward, F.A., Dvorak, F.A., and Geller, E.W.: A Computer Program for Three-Dimensional Lifting Bodies in Subsonic Flow. Flow Research, Inc. Rept. USA AMRDL-TR-74-18, Apr. 1974.

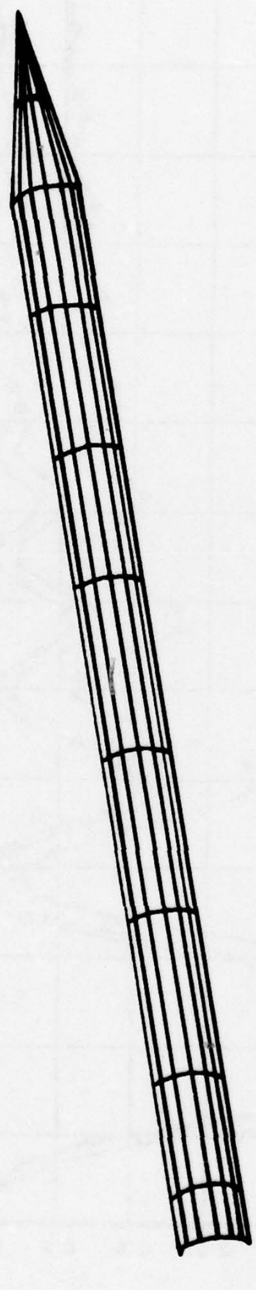

Figure 1. Missile panel distribution.

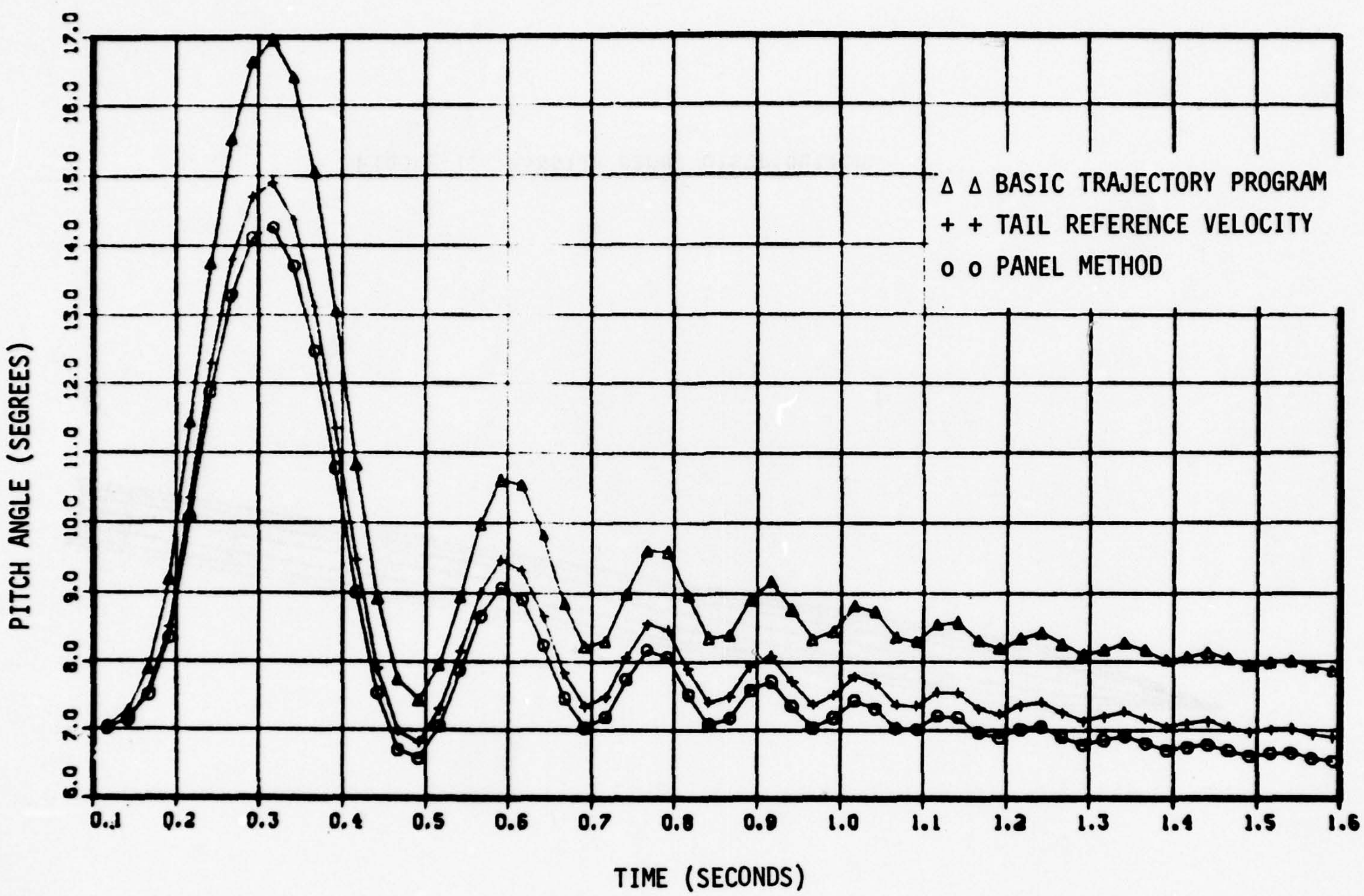

Figure 2. Instantaneous pitch angle for triangular downwash

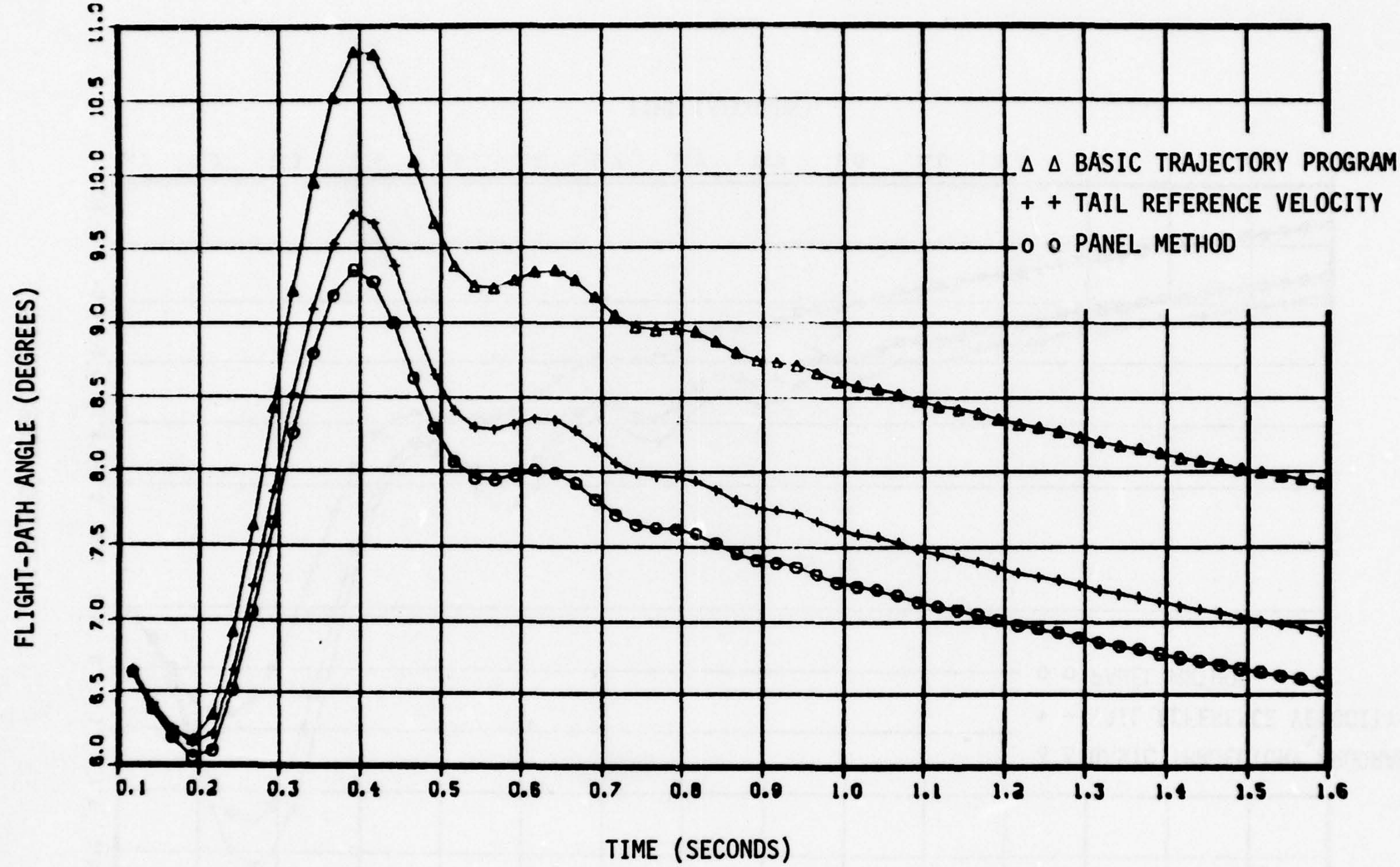

Figure 3. Flight-path angle for triangular downwash

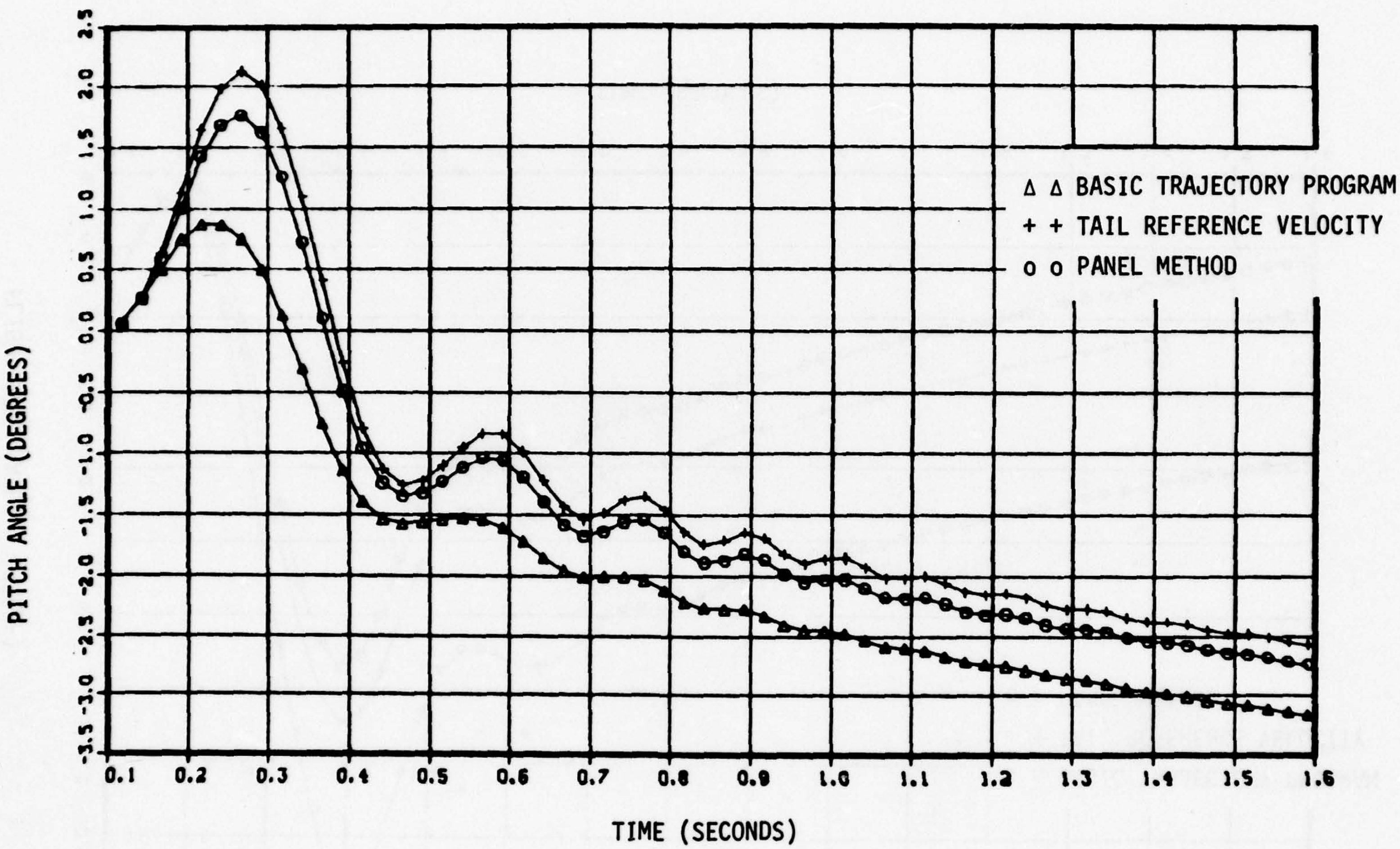

Figure 4. Instantaneous pitch angle for helicopter downwash

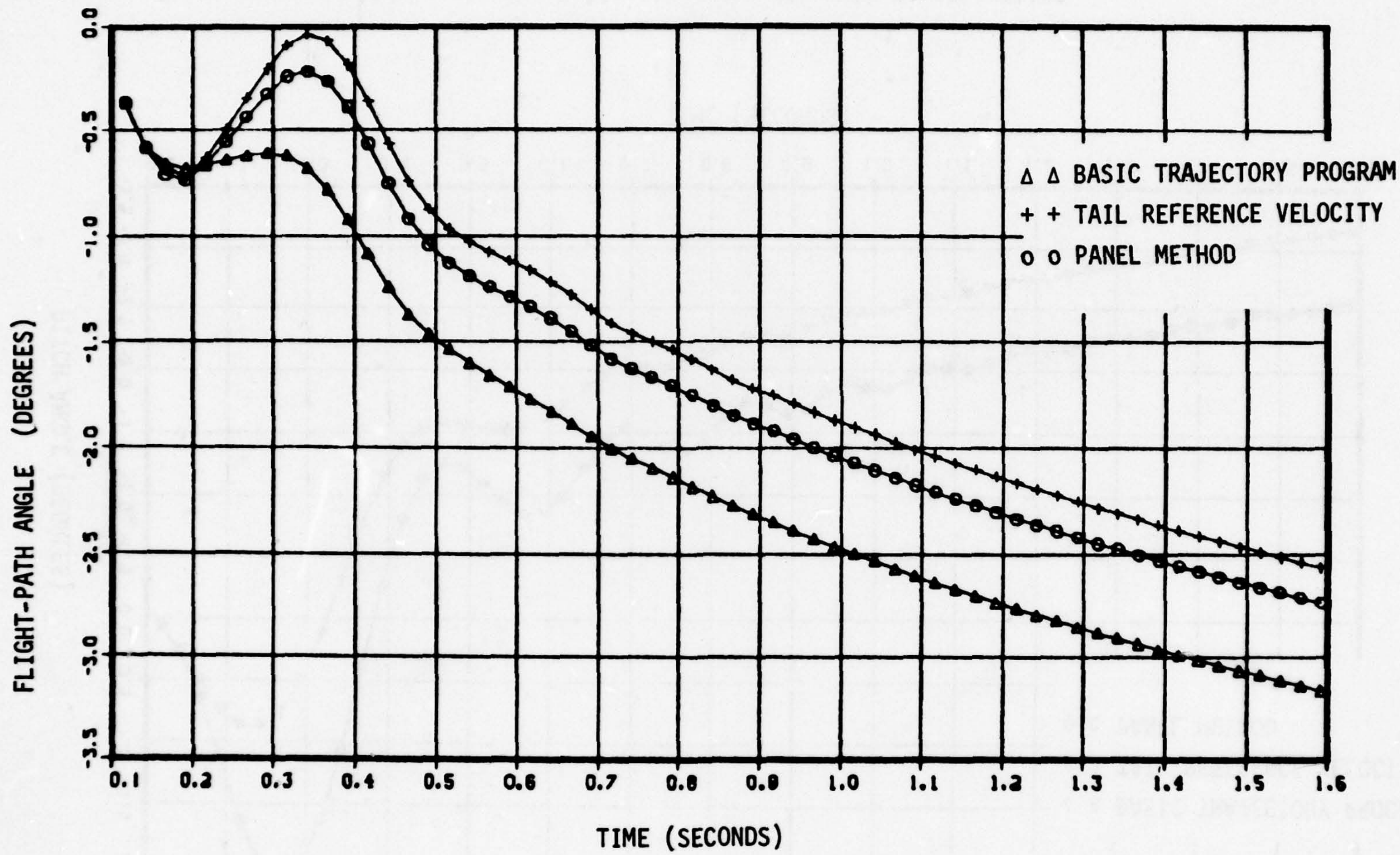

Figure 5. Flight-path angle for helicopter downwash.

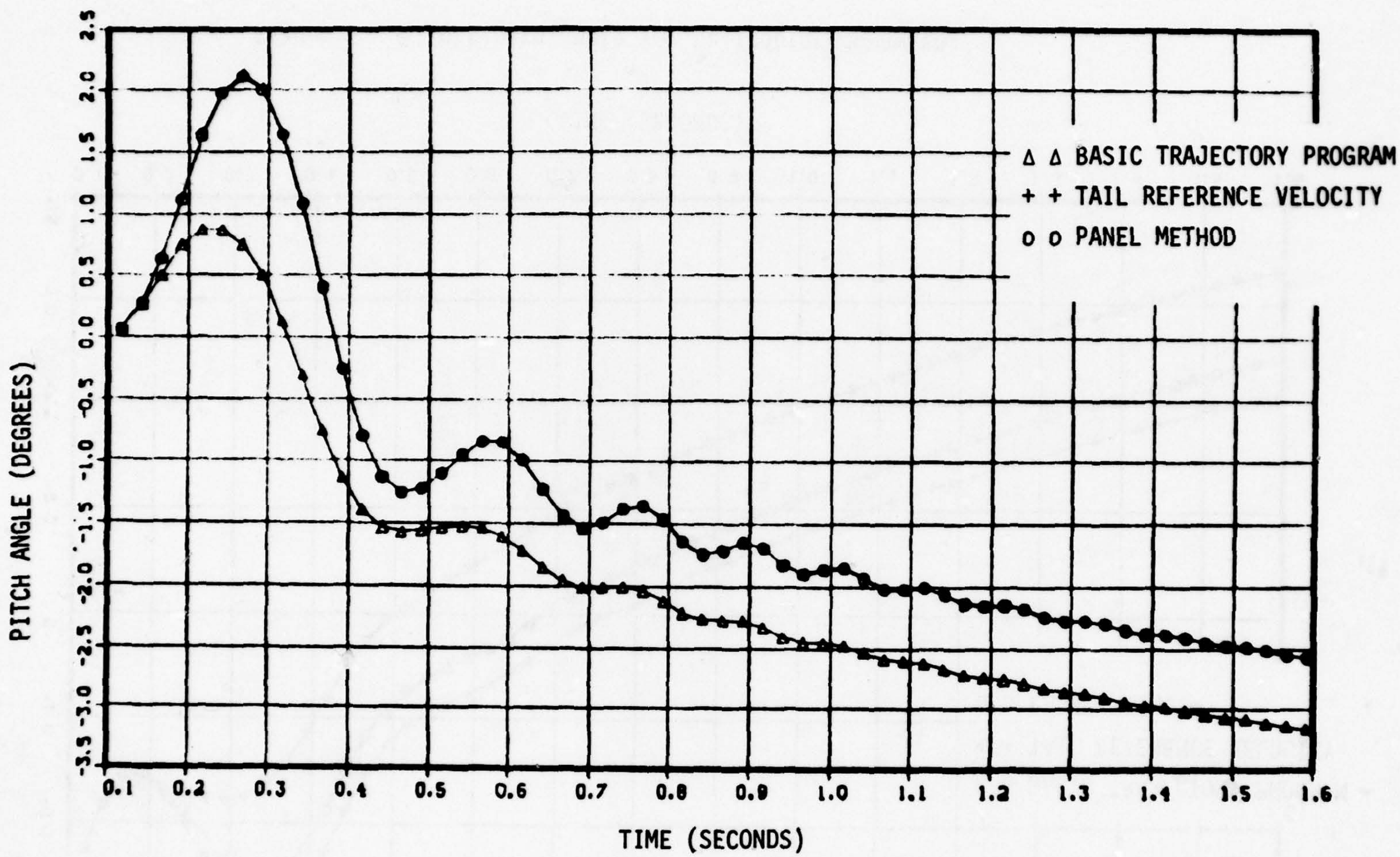

Figure 6. Instantaneous pitch angle for helicopter downwash with no separation.

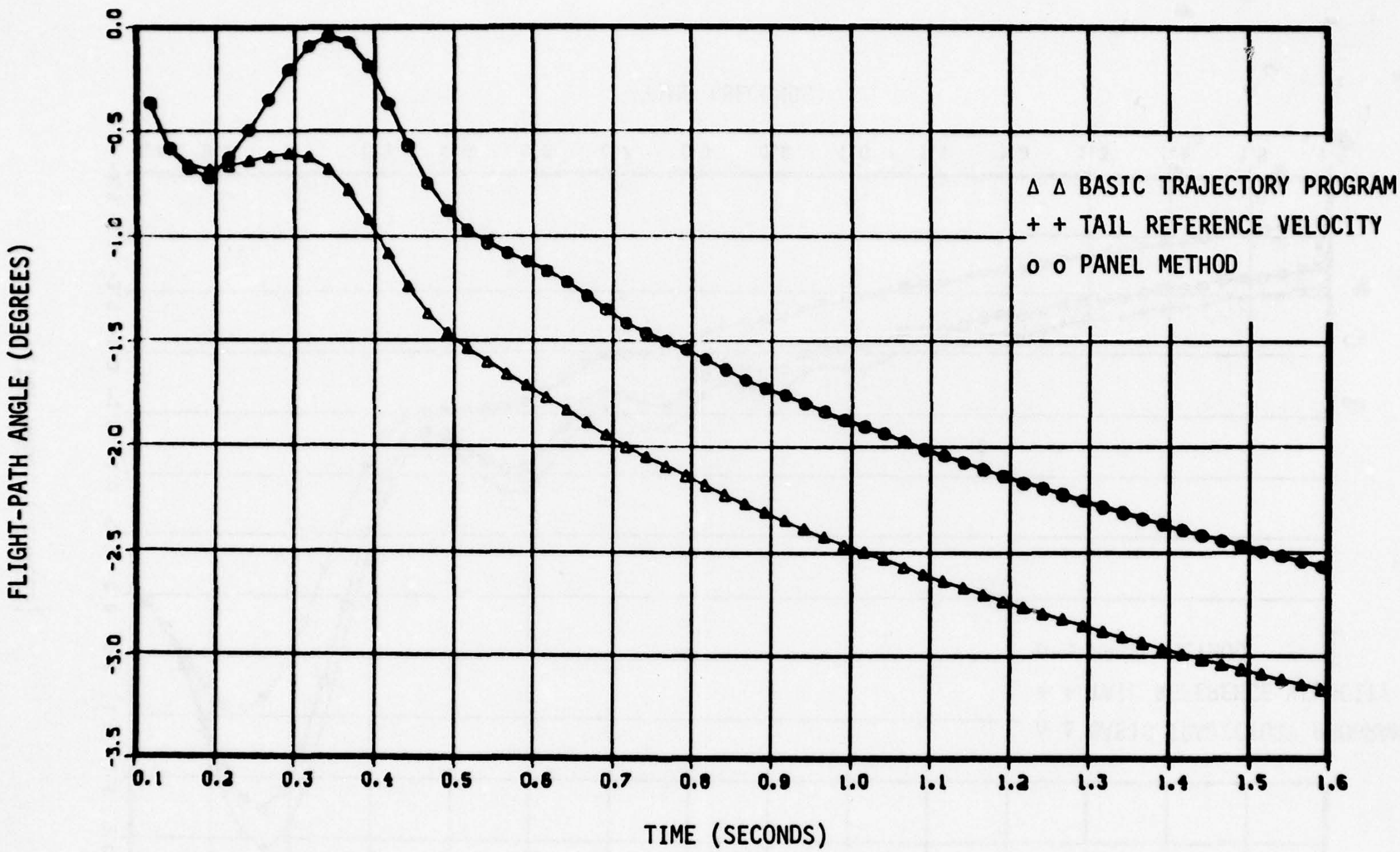

Figure 7. Flight-path angle for helicopter downwash with no separation.

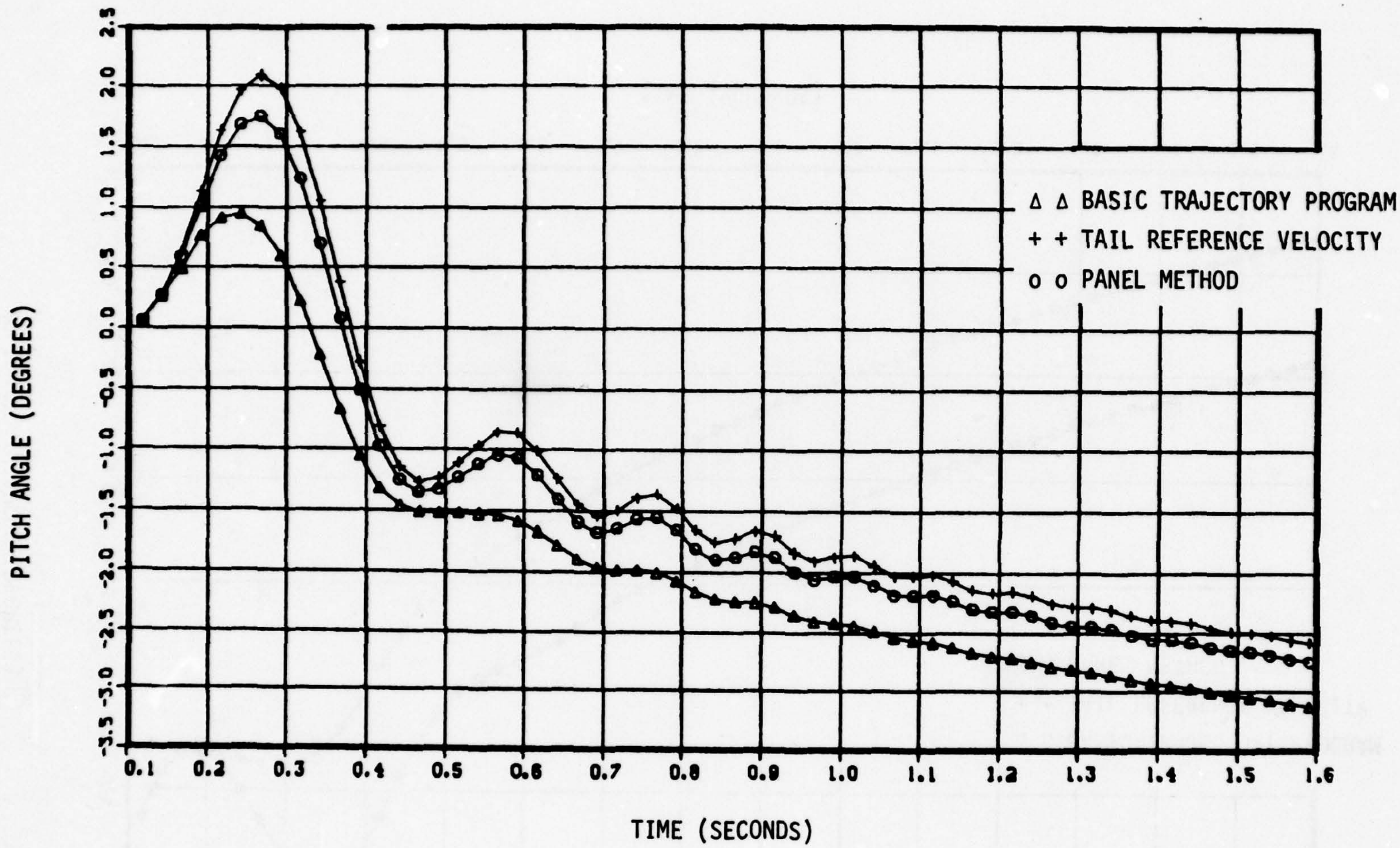

Figure 8. Instantaneous pitch angle for helicopter downwash with rotor blades initially at 45°.

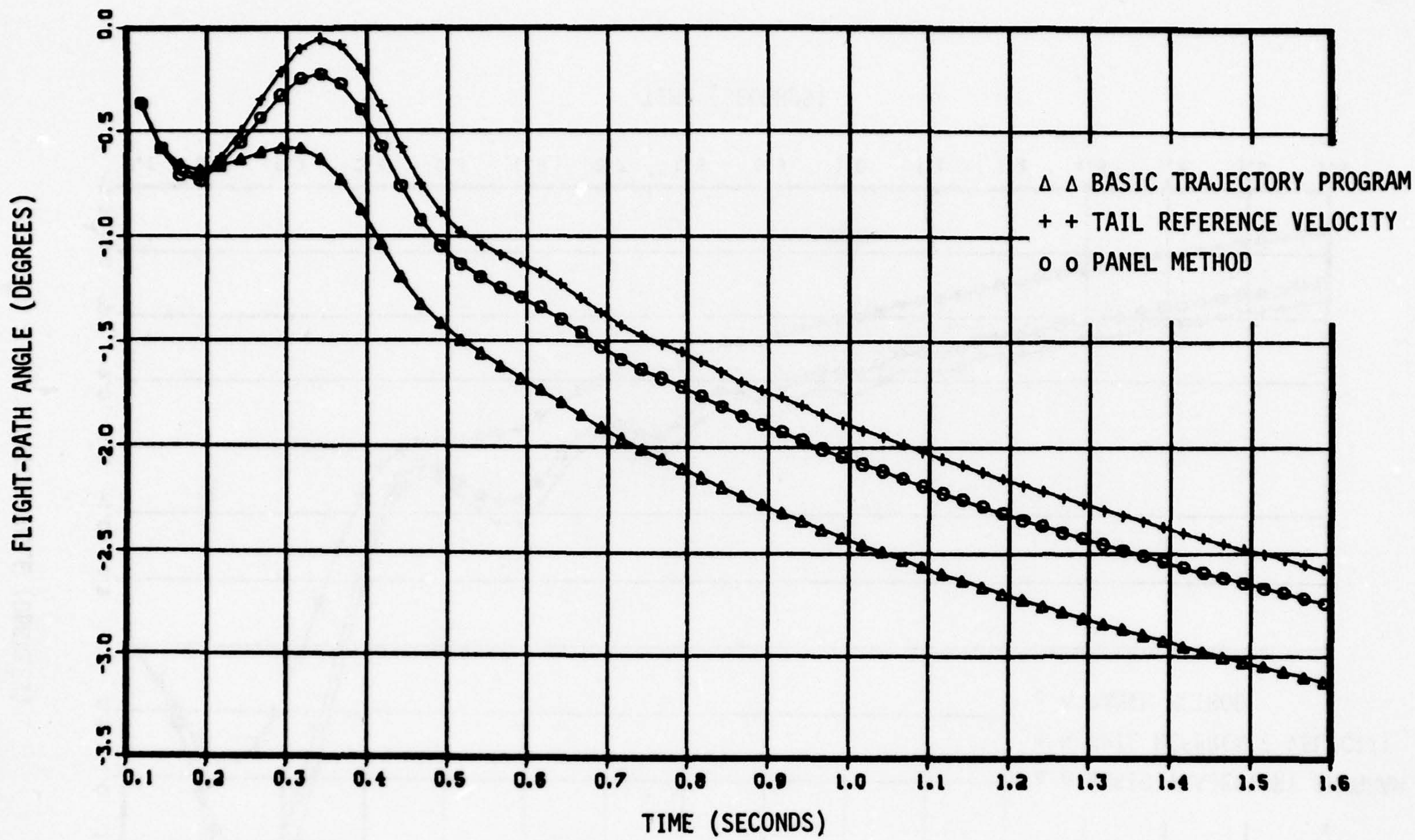

Figure 9. Flight-path angle for helicopter downwash with rotor blades initially at 45°.

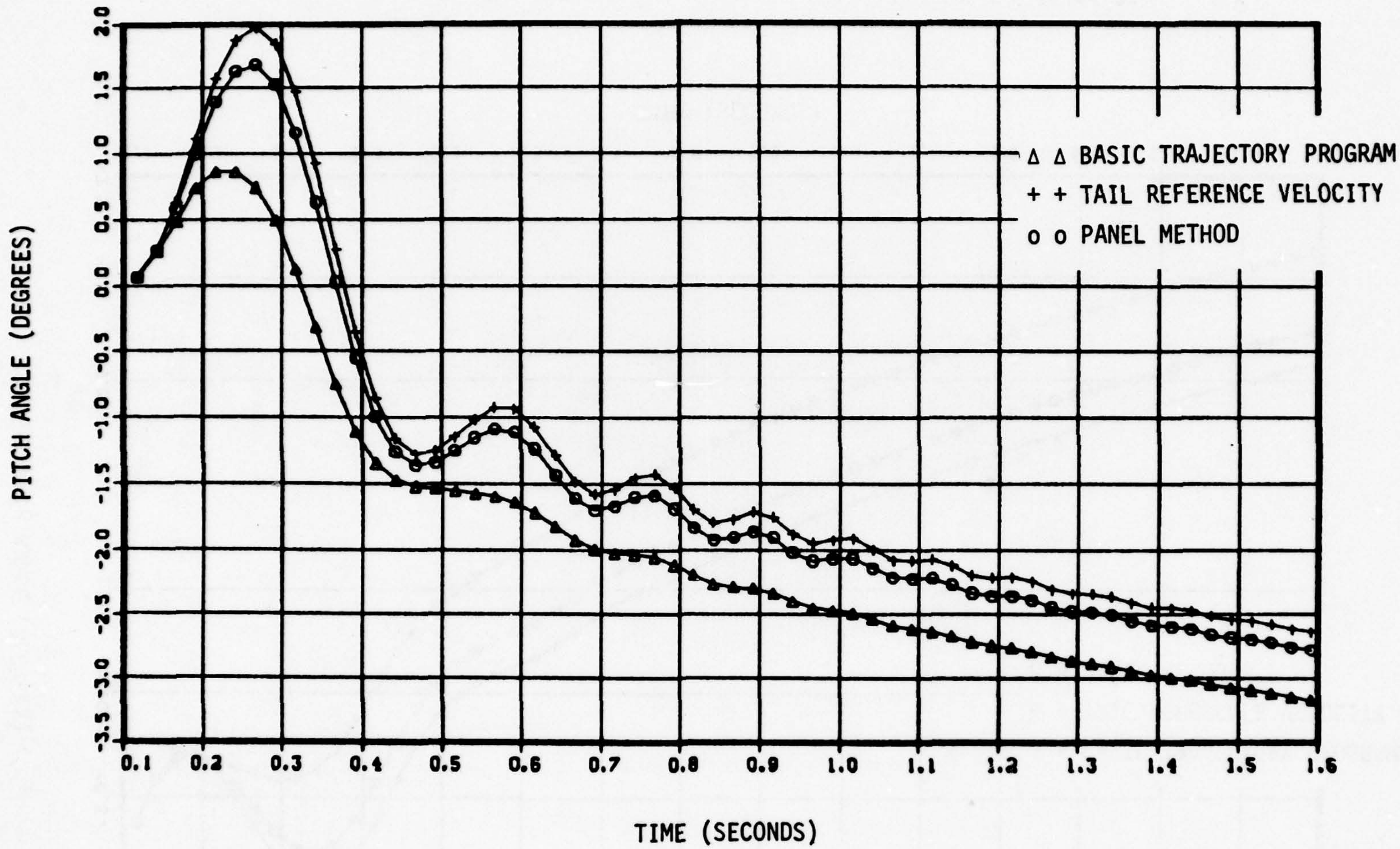

Figure 10. Instantaneous pitch angle for helicopter downwash with rotor blades initially at 90°.

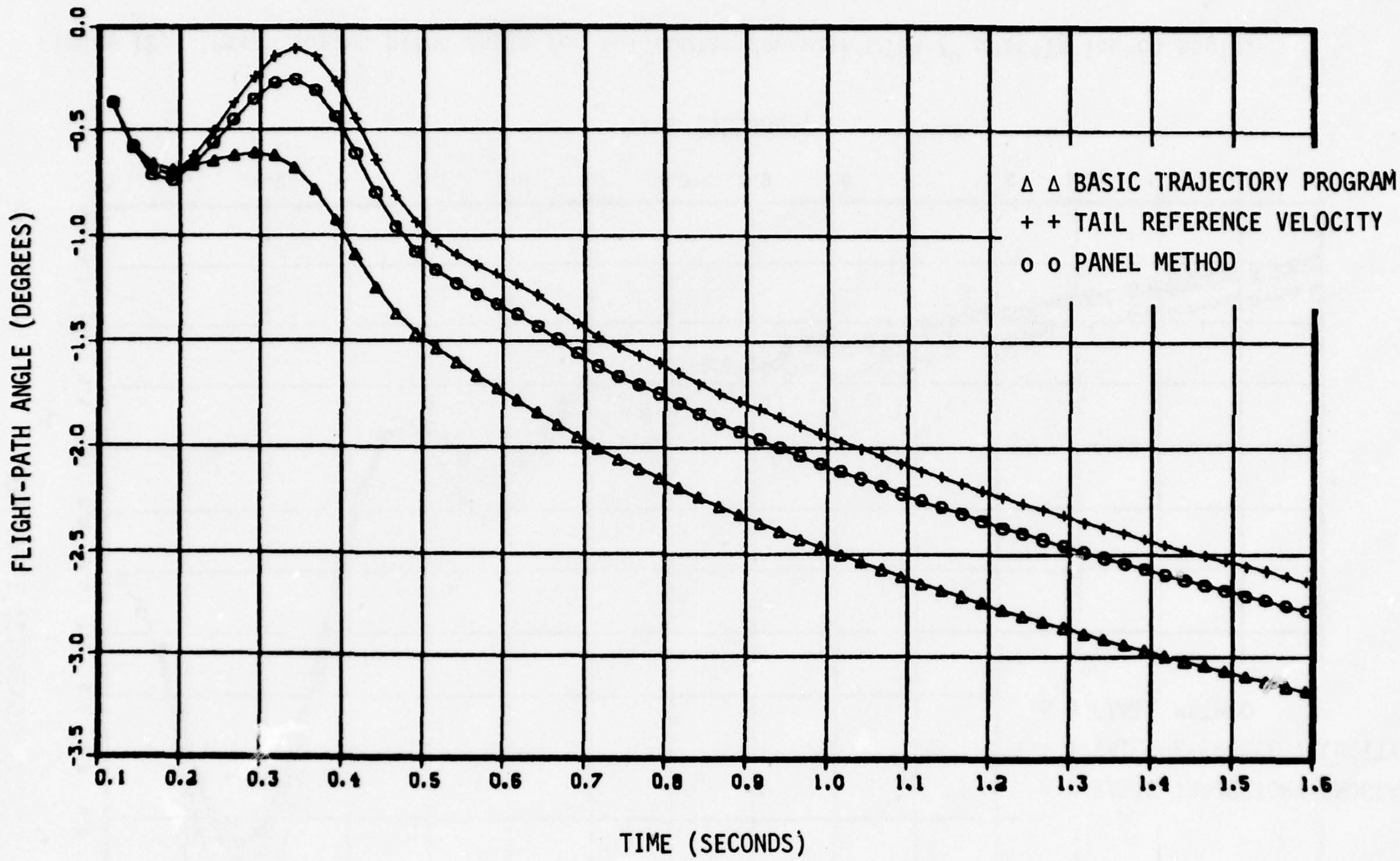

Figure 11. Flight-path angle for helicopter downwash with rotor blades initially at 90°.

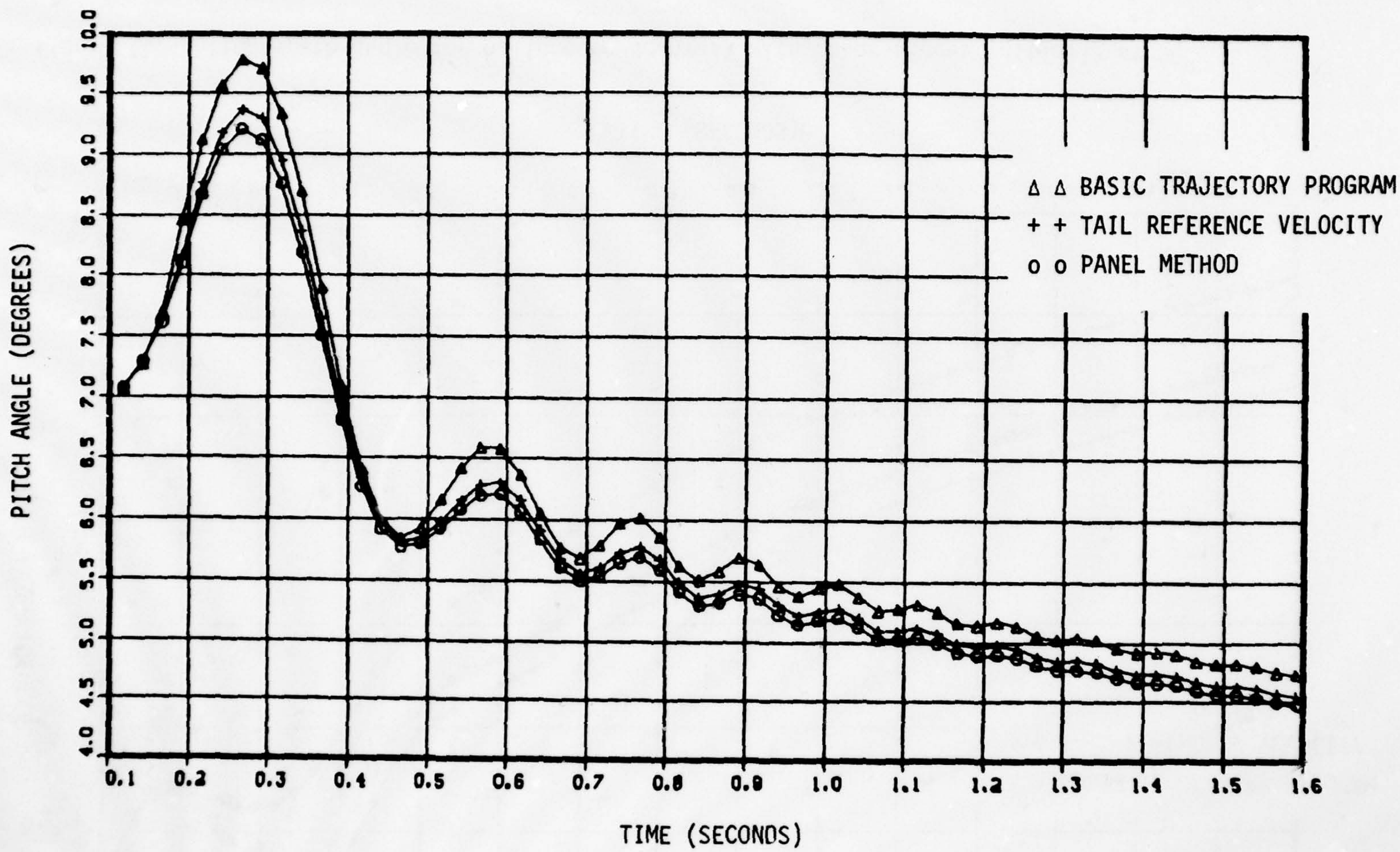

Figure 12. Instantaneous pitch angle for helicopter downwash with 7^{o} missile launch angle.

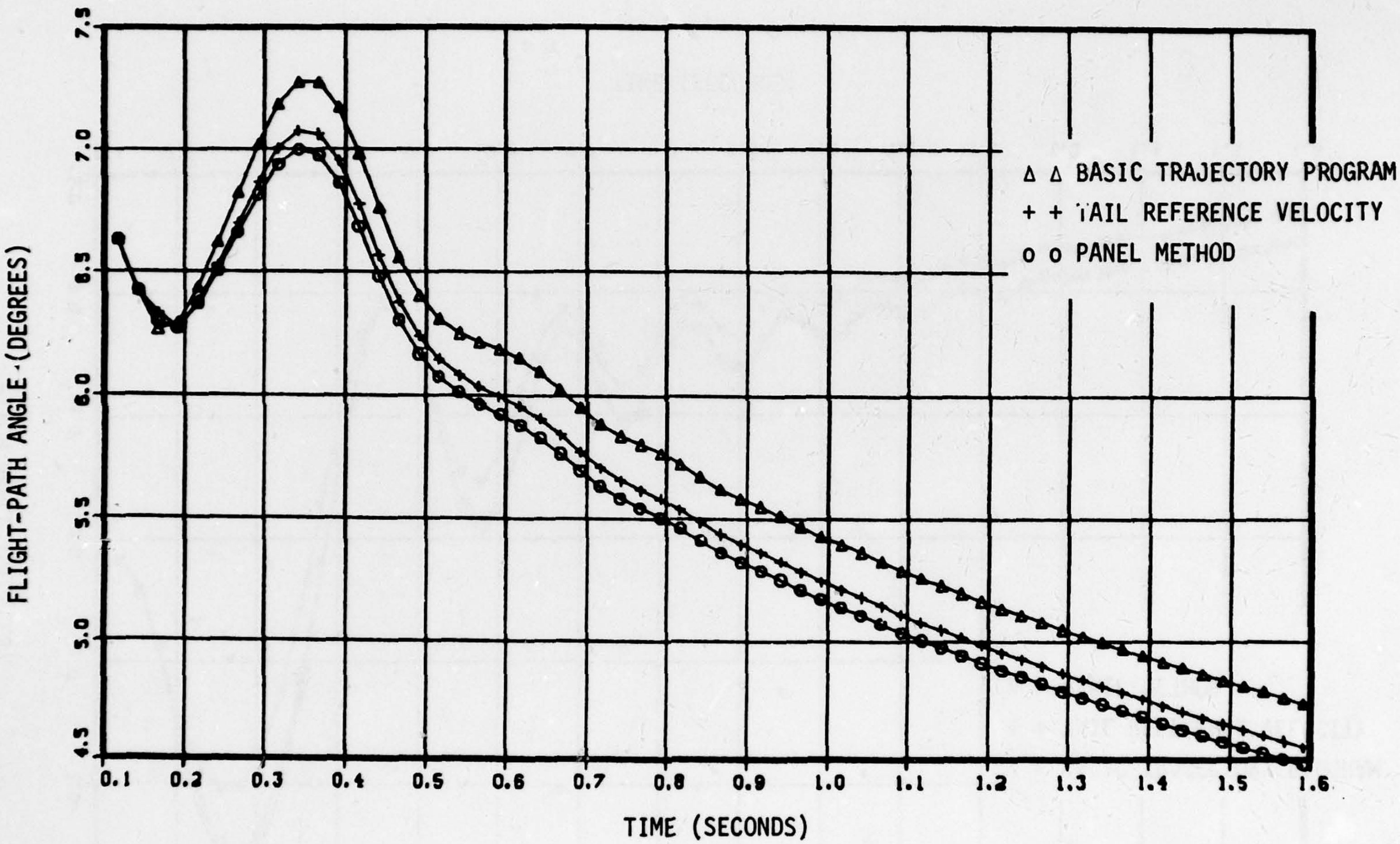

Figure 13. Flight-path angle for helicopter downwash with 7^{o} missile launch angle.

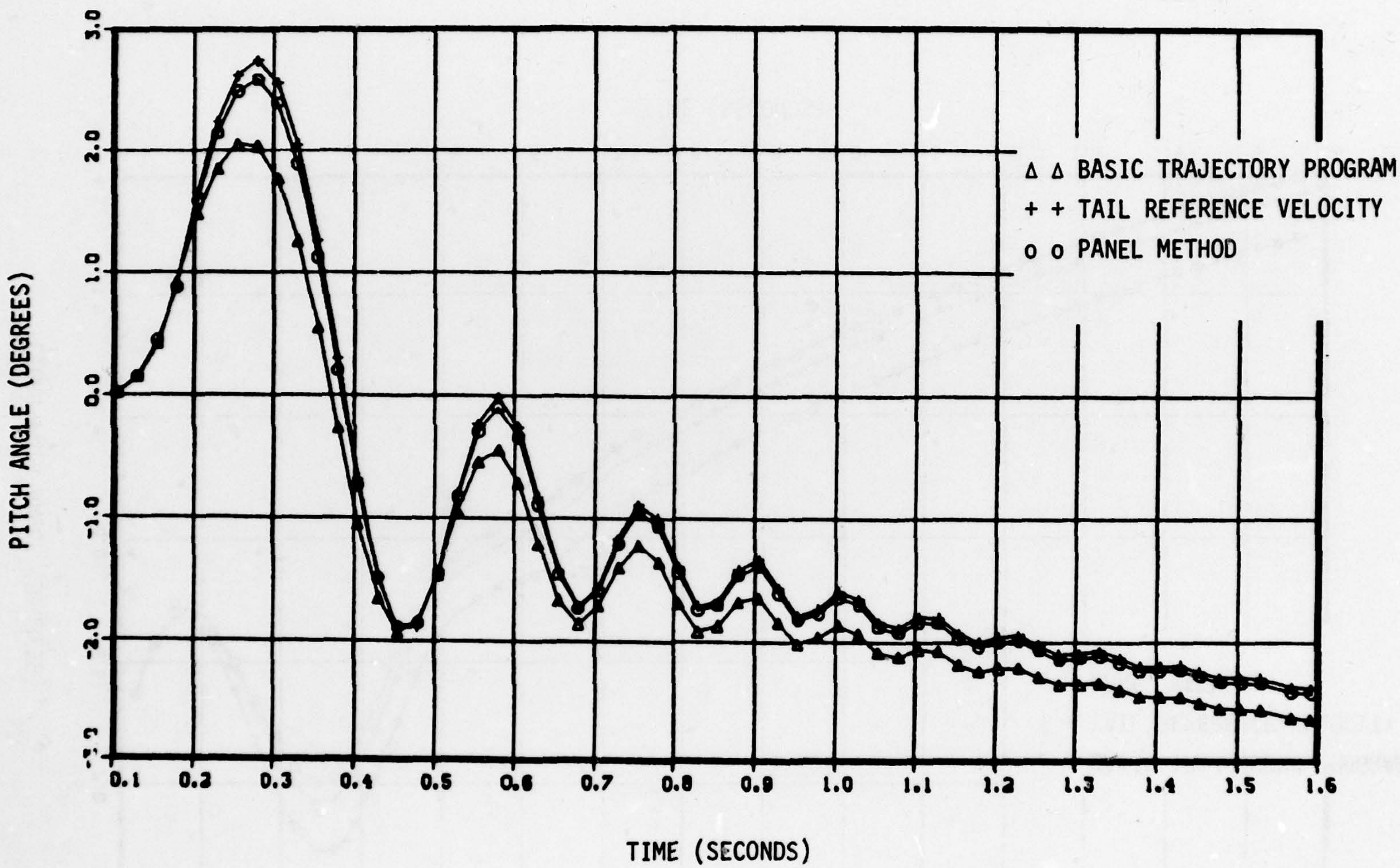

Figure 14. Instantaneous pitch angle for helicopter downwash using 0.0125 sec. time step.

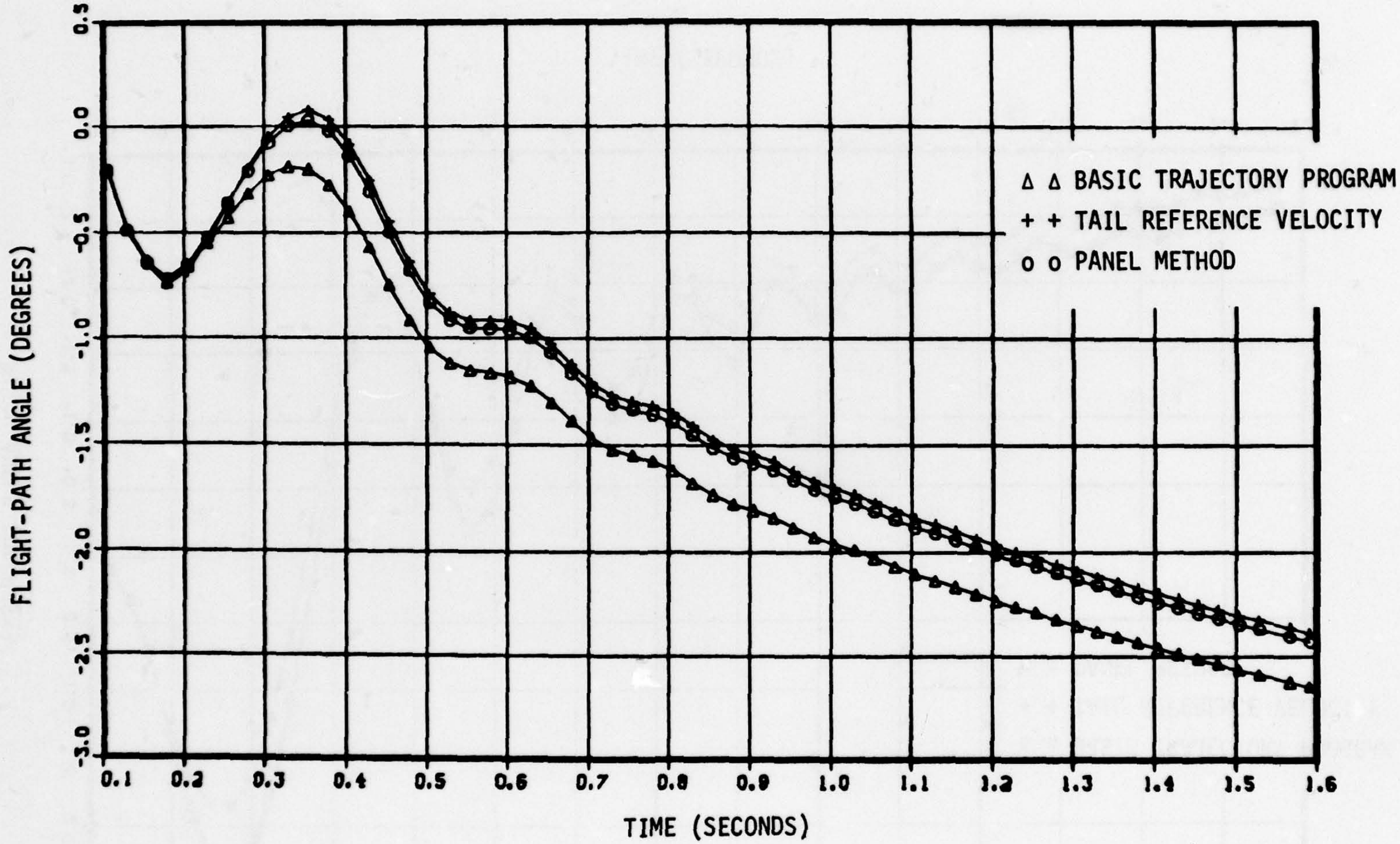

Figure 15. Flight-path angle for helicopter downwash using 0.0125 sec. time step.

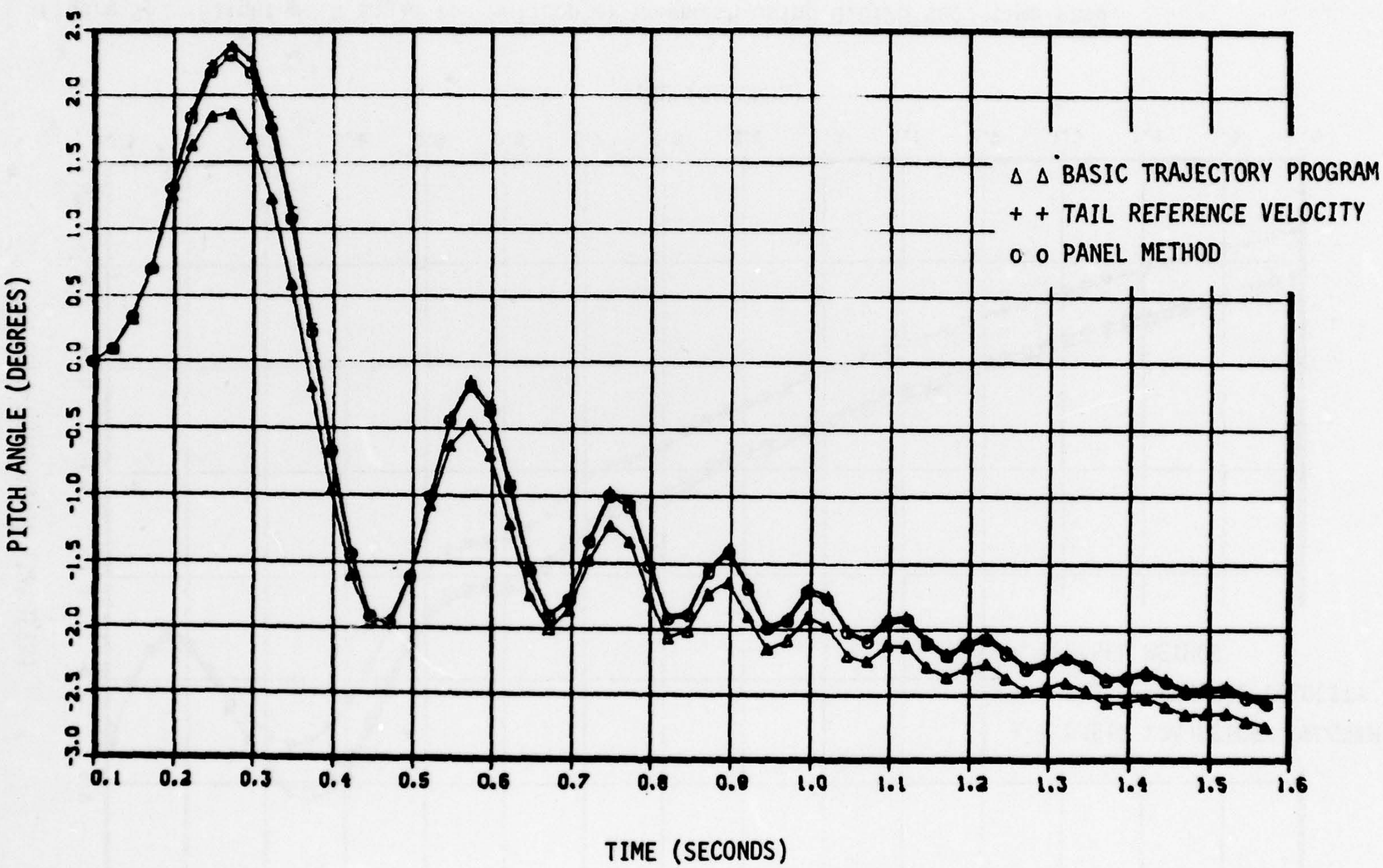

Figure 16. Instantaneous pitch angle for helicopter downwash using 0.005 sec. time step.

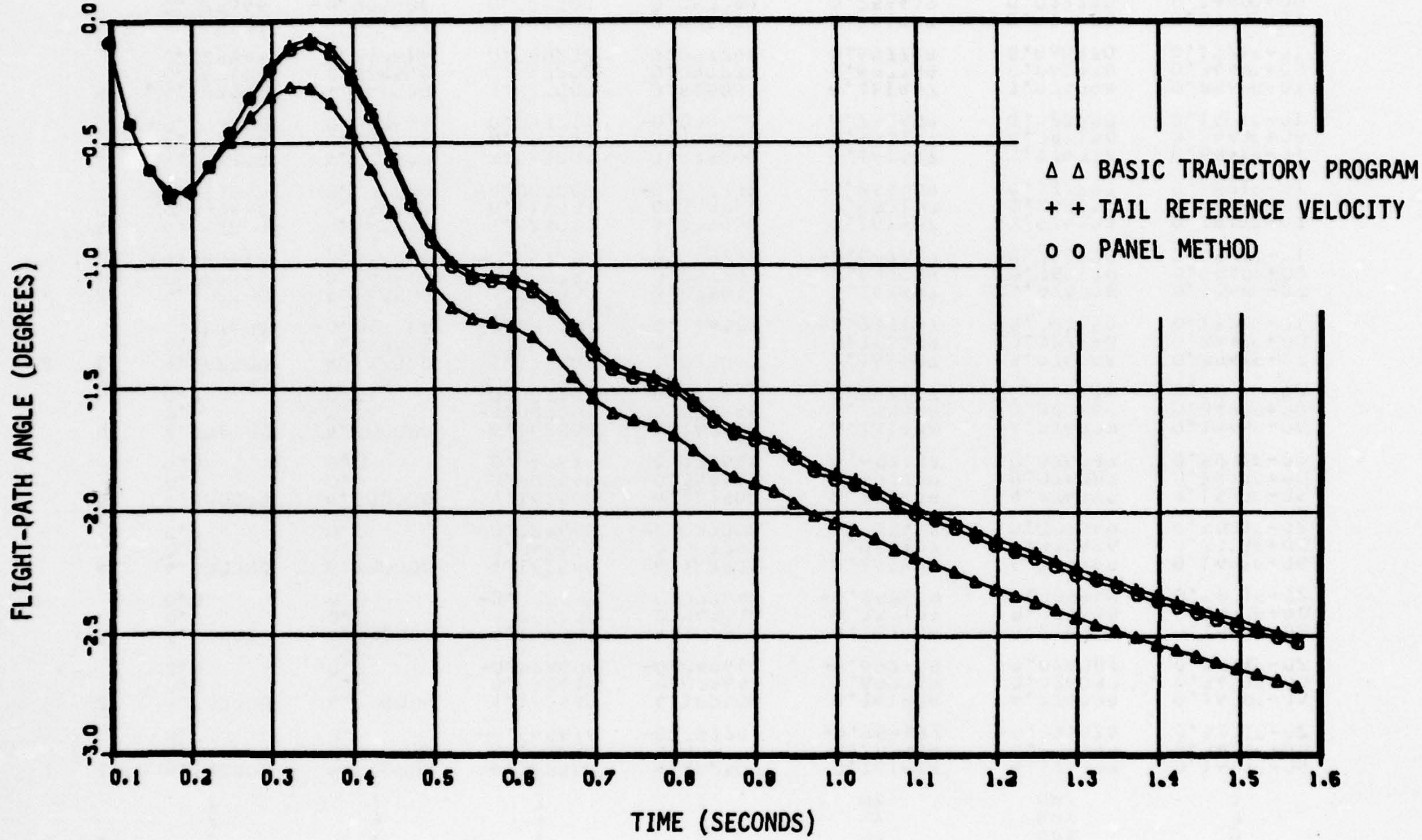

Figure 17. Flight-path angle for helicopter downwash using 0.005 sec. time step.

PROGRAM BOXC DOUGLAS AIRCRAFT COMPANY PAGE 1
LONG BEACH DIVISION
CASE NO. 2 TUESDAY, JUL 31, 1979
10 X 6 MISSILE - ONE PLANE OF SYMMETRY TEST CASE

THERE IS ONE PLANE OF SYMMETRY

GENERATE A 10 X 6 BODY. B = 1.00000 C = -1.00000

PAGE 2

N	M	X Y Z	X Y Z	X Y Z	X Y Z	NX NY NZ	NPX NPY NPZ	D T A
1	1	4.500000 0.0 0.0	4.500000 0.0 0.0	4.162500 0.028646 -0.049616	4.162500 0.0 -0.057292	0.161808 0.255409 -0.953197	4.274999 0.009549 -0.035636	0.1602E-06 0.3423E+00 0.5071E-02
	2	4.500000 0.0 0.0	4.500000 0.0 0.0	4.162500 0.049616 -0.028646	4.162500 0.028646 -0.049616	0.161808 0.697789 -0.697789	4.274999 0.026087 -0.026087	0.1639E-06 0.3423E+00 0.5071E-02
	3	4.500000 0.0 0.0	4.500000 0.0 0.0	4.162500 0.057292 -0.000000	4.162500 0.049616 -0.028646	0.161808 0.953197 -0.255409	4.274999 0.035636 -0.009549	0.1583E-06 0.3423E+00 0.5071E-02
	4	4.500000 0.0 0.0	4.500000 0.0 0.0	4.162500 0.049616 0.028646	4.162500 0.057292 -0.000000	0.161808 0.953197 0.255408	4.274999 0.035636 0.009549	0.1681E-06 0.3423E+00 0.5071E-02
	5	4.500000 0.0 0.0	4.500000 0.0 0.0	4.162500 0.028646 0.049616	4.162500 0.049616 0.028645	0.161808 0.697789 0.697788	4.274999 0.026087 0.026087	0.1527E-06 0.3423E+00 0.5071E-02
	6	4.500000 0.0 0.0	4.500000 0.0 0.0	4.162500 -0.000000 0.057292	4.162500 0.028646 0.049616	0.161808 0.255408 0.953197	4.274999 0.009549 0.035636	0.1565E-06 0.3423E+00 0.5071E-02
2	1	4.162500 0.0 -0.057292	4.162500 0.028646 -0.049616	3.825000 0.057291 -0.099232	3.825000 0.0 -0.114583	0.161807 0.255408 -0.953197	3.974998 0.022280 -0.083150	0.8941E-07 0.3449E+00 0.1521E-01
	2	4.162500 0.028646 -0.049616	4.162500 0.049616 -0.028646	3.825000 0.099232 -0.057292	3.825000 0.057291 -0.099232	0.161807 0.697789 -0.697789	3.974998 0.060870 -0.060870	0.8568E-07 0.3449E+00 0.1521E-01
	3	4.162500 0.049616 -0.028646	4.162500 0.057292 -0.000000	3.825000 0.114583 -0.000000	3.825000 0.099232 -0.057292	0.161807 0.953197 -0.255409	3.974998 0.083150 -0.022280	0.7893E-07 0.3449E+00 0.1521E-01
	4	4.162500 0.057292 -0.000000	4.162500 0.049616 0.028646	3.825000 0.099232 0.057291	3.825000 0.114583 -0.000000	0.161807 0.953197 0.255408	3.974998 0.083150 0.022280	0.8941E-07 0.3449E+00 0.1521E-01
	5	4.162500 0.049616 0.028646	4.162500 0.028646 0.049616	3.825000 0.057292 0.099232	3.825000 0.099232 0.057291	0.161807 0.697789 0.697788	3.974998 0.060870 0.060870	0.8568E-07 0.3449E+00 0.1521E-01
	6	4.162500 0.028646 0.049616	4.162500 -0.000000 0.057292	3.825000 -0.000000 0.114583	3.825000 0.057292 0.099232	0.161807 0.255409 0.953197	3.974998 0.022280 0.083150	0.5960E-07 0.3449E+00 0.1521E-01

Figure 18a. Panel method output for test case.

PROGRAM BOXC
CASE NO. 2

DOUGLAS AIRCRAFT COMPANY
LONG BEACH DIVISION
TUESDAY, JUL 31, 1979
10 X 6 MISSILE - ONE PLANE OF SYMMETRY TEST CASE

N	M	X Y Z	X Y Z	X Y Z	X Y Z	NX NY NZ	NPX NPY NPZ	D T A
3	1	3.825000 0.0 -0.114583	3.825000 0.057291 -0.099232	3.425000 0.057291 -0.099232	3.425000 0.0 -0.114583	0.0 0.258819 -0.965926	3.625000 0.028646 -0.106907	0.3353E-07 0.4044E+00 0.2372E-01
	2	3.825000 0.057291 -0.099232	3.825000 0.099232 -0.057292	3.425000 0.099232 -0.057292	3.425000 0.057291 -0.099232	0.0 0.707107 -0.707107	3.625000 0.078262 -0.078262	0.4098E-07 0.4044E+00 0.2372E-01
	3	3.825000 0.099232 -0.057292	3.825000 0.114583 -0.000000	3.425000 0.114583 -0.000000	3.425000 0.099232 -0.057292	0.0 0.965926 -0.258819	3.625000 0.106907 -0.028646	0.2608E-07 0.4044E+00 0.2372E-01
	4	3.825000 0.114583 -0.000000	3.825000 0.099232 0.057291	3.425000 0.099232 0.057291	3.425000 0.114583 -0.000000	0.0 0.965926 0.258819	3.625000 0.106907 0.028646	0.3725E-07 0.4044E+00 0.2372E-01
	5	3.825000 0.099232 0.057291	3.825000 0.057292 0.099232	3.425000 0.057292 0.099232	3.425000 0.099232 0.057291	0.0 0.707107 0.707107	3.625000 0.078262 0.078262	0.5960E-07 0.4044E+00 0.2372E-01
	6	3.825000 0.057292 0.099232	3.825000 -0.000000 0.114583	3.425000 -0.000000 0.114583	3.425000 0.057292 0.099232	0.0 0.258820 0.965926	3.625000 0.028646 0.106907	0.0 0.4044E+00 0.2372E-01
	1	3.425000 0.0 -0.114583	3.425000 0.057291 -0.099232	2.900000 0.057291 -0.099232	2.900000 0.0 -0.114583	0.0 0.258819 -0.965926	3.162498 0.028646 -0.106907	0.3353E-07 0.5283E+00 0.3114E-01
	2	3.425000 0.057291 -0.099232	3.425000 0.099232 -0.057292	2.900000 0.099232 -0.057292	2.900000 0.057291 -0.099232	0.0 0.707107 -0.707107	3.162498 0.078262 -0.078262	0.4098E-07 0.5283E+00 0.3114E-01
	3	3.425000 0.099232 -0.057292	3.425000 0.114583 -0.000000	2.900000 0.114583 -0.000000	2.900000 0.099232 -0.057292	0.0 0.965926 -0.258819	3.162498 0.106907 -0.028646	0.2608E-07 0.5283E+00 0.3114E-01
	4	3.425000 0.114583 -0.000000	3.425000 0.099232 0.057291	2.900000 0.099232 0.057291	2.900000 0.114583 -0.000000	0.0 0.965926 0.258819	3.162498 0.106907 0.028646	0.3725E-07 0.5283E+00 0.3114E-01
	5	3.425000 0.099232 0.057291	3.425000 0.057292 0.099232	2.900000 0.057292 0.099232	2.900000 0.099232 0.057291	0.0 0.707107 0.707106	3.162498 0.078262 0.078261	0.5960E-07 0.5283E+00 0.3114E-01
	6	3.425000 0.057292 0.099232	3.425000 -0.000000 0.114583	2.900000 -0.000000 0.114583	2.900000 0.057292 0.099232	0.0 0.258820 0.965926	3.162498 0.028646 0.106907	0.0 0.5283E+00 0.3114E-01

Figure 18a. (continued)

. PROGRAM BOXC DOUGLAS AIRCRAFT COMPANY
LONG BEACH DIVISION
TUESDAY, JUL 31, 1979
10 X 6 MISSILE - ONE PLANE OF SYMMETRY TEST CASE

CASE NO. 2 PAGE 4

N	M	X Y Z	X Y Z	X Y Z	X Y Z	NX NY NZ	NPX NPY NPZ	D T A
5	1	2.900000 0.0 -0.114583	2.900000 0.057291 -0.099232	2.400000 0.057291 -0.099232	2.400000 0.0 -0.114583	0.0 0.258819 -0.965926	2.650000 0.028646 -0.106907	0.2980E-07 0.5035E+00 0.2966E-01
	2	2.900000 0.057291 -0.099232	2.900000 0.099232 -0.057292	2.400000 0.099232 -0.057292	2.400000 0.057291 -0.099232	0.0 0.707107 -0.707107	2.650000 0.078262 -0.078262	0.4098E-07 0.5035E+00 0.2966E-01
	3	2.900000 0.099232 -0.057292	2.900000 0.114583 -0.000000	2.400000 0.114583 -0.000000	2.400000 0.099232 -0.057292	0.0 0.965926 -0.258820	2.650000 0.106907 -0.028646	0.2980E-07 0.5035E+00 0.2966E-01
	4	2.900000 0.114583 -0.000000	2.900000 0.099232 0.057291	2.400000 0.099232 0.057291	2.400000 0.114583 -0.000000	0.0 0.965926 0.258819	2.650000 0.106907 0.028646	0.3353E-07 0.5035E+00 0.2966E-01
	5	2.900000 0.099232 0.057291	2.900000 0.057292 0.099232	2.400000 0.057292 0.099232	2.400000 0.099232 0.057291	0.0 0.707107 0.707107	2.650000 0.078262 0.078262	0.5960E-07 0.5035E+00 0.2966E-01
	6	2.900000 0.057292 0.099232	2.900000 -0.000000 0.114583	2.400000 -0.000000 0.114583	2.400000 0.057292 0.099232	0.0 0.258820 0.965926	2.650000 0.028646 0.106907	0.0 0.5035E+00 0.2966E-01
6	1	2.400000 0.0 -0.114583	2.400000 0.057291 -0.099232	1.800000 0.057291 -0.099232	1.800000 0.0 -0.114583	0.0 0.258820 -0.965926	2.099998 0.028646 -0.106907	0.2980E-07 0.6029E+00 0.3559E-01
	2	2.400000 0.057291 -0.099232	2.400000 0.099232 -0.057292	1.800000 0.099232 -0.057292	1.800000 0.057291 -0.099232	0.0 0.707107 -0.707107	2.099998 0.078262 -0.078262	0.3725E-07 0.6029E+00 0.3559E-01
	3	2.400000 0.099232 -0.057292	2.400000 0.114583 -0.000000	1.800000 0.114583 -0.000000	1.800000 0.099232 -0.057292	0.0 0.965926 -0.258820	2.099998 0.106907 -0.028646	0.3353E-07 0.6029E+00 0.3559E-01
	4	2.400000 0.114583 -0.000000	2.400000 0.099232 0.057291	1.800000 0.099232 0.057291	1.800000 0.114583 -0.000000	0.0 0.965926 0.258820	2.099998 0.106907 0.028646	0.3353E-07 0.6029E+00 0.3559E-01
	5	2.400000 0.099232 0.057291	2.400000 0.057292 0.099232	1.800000 0.057292 0.099232	1.800000 0.099232 0.057291	0.0 0.707107 0.707107	2.099998 0.078262 0.078261	0.5960E-07 0.6029E+00 0.3559E-01
	6	2.400000 0.057292 0.099232	2.400000 -0.000000 0.114583	1.800000 -0.000000 0.114583	1.800000 0.057292 0.099232	0.0 0.258820 0.965925	2.099998 0.028646 0.106907	0.3725E-08 0.6029E+00 0.3559E-01

Figure 18a. (continued)

PROGRAM BOXC DOUGLAS AIRCRAFT COMPANY
LONG BEACH DIVISION PAGE 5
CASE NO. 2 TUESDAY, JUL 31, 1979
10 X 6 MISSILE - ONE PLANE OF SYMMETRY TEST CASE

N	M	X / Y / Z	X / Y / Z	X / Y / Z	X / Y / Z	NX / NY / NZ	NPX / NPY / NPZ	D / T / A
7	1	1.800000	1.800000	1.200000	1.200000	0.0	1.500000	0.2608E-07
		0.0	0.057291	0.057291	0.0	0.258820	0.028646	0.6029E+00
		-0.114583	-0.099232	-0.099232	-0.114583	-0.965926	-0.106907	0.3559E-01
	2	1.800000	1.800000	1.200000	1.200000	0.0	1.500000	0.3725E-07
		0.057291	0.099232	0.099232	0.057291	0.707107	0.078262	0.6029E+00
		-0.099232	-0.057292	-0.057292	-0.099232	-0.707107	-0.078262	0.3559E-01
	3	1.800000	1.800000	1.200000	1.200000	0.0	1.500000	0.3353E-07
		0.099232	0.114583	0.114583	0.099232	0.965926	0.106907	0.6029E+00
		-0.057292	-0.000000	-0.000000	-0.057292	-0.258820	-0.028646	0.3559E-01
	4	1.800000	1.800000	1.200000	1.200000	0.0	1.500000	0.2608E-07
		0.114583	0.099232	0.099232	0.114583	0.965926	0.106907	0.6029E+00
		-0.000000	0.057291	0.057291	-0.000000	0.258820	0.028646	0.3559E-01
	5	1.800000	1.800000	1.200000	1.200000	0.0	1.500000	0.6333E-07
		0.099232	0.057292	0.057292	0.099232	0.707107	0.078262	0.6029E+00
		0.057291	0.099232	0.099232	0.057291	0.707107	0.078262	0.3559E-01
	6	1.800000	1.800000	1.200000	1.200000	0.0	1.500000	0.3725E-08
		0.057292	-0.000000	-0.000000	0.057292	0.258820	0.028646	0.6029E+00
		0.099232	0.114583	0.114583	0.099232	0.965926	0.106907	0.3559E-01
8	1	1.200000	1.200000	0.600000	0.600000	0.0	0.900000	0.2980E-07
		0.0	0.057291	0.057291	0.0	0.258820	0.028646	0.6029E+00
		-0.114583	-0.099232	-0.099232	-0.114583	-0.965926	-0.106907	0.3559E-01
	2	1.200000	1.200000	0.600000	0.600000	0.0	0.899999	0.4098E-07
		0.057291	0.099232	0.099232	0.057291	0.707107	0.078262	0.6029E+00
		-0.099232	-0.057292	-0.057292	-0.099232	-0.707107	-0.078262	0.3559E-01
	3	1.200000	1.200000	0.600000	0.600000	0.0	0.899999	0.2980E-07
		0.099232	0.114583	0.114583	0.099232	0.965926	0.106907	0.6029E+00
		-0.057292	-0.000000	-0.000000	-0.057292	-0.258820	-0.028646	0.3559E-01
	4	1.200000	1.200000	0.600000	0.600000	0.0	0.900000	0.2980E-07
		0.114583	0.099232	0.099232	0.114583	0.965926	0.106907	0.6029E+00
		-0.000000	0.057291	0.057291	-0.000000	0.258820	0.028646	0.3559E-01
	5	1.200000	1.200000	0.600000	0.600000	0.0	0.899999	0.5960E-07
		0.099232	0.057292	0.057292	0.099232	0.707107	0.078262	0.6029E+00
		0.057291	0.099232	0.099232	0.057291	0.707106	0.078262	0.3559E-01
	6	1.200000	1.200000	0.600000	0.600000	0.0	0.900000	0.3725E-08
		0.057292	-0.000000	-0.000000	0.057292	0.258820	0.028646	0.6029E+00
		0.099232	0.114583	0.114583	0.099232	0.965926	0.106907	0.3559E-01

Figure 18a. (continued)

PROGRAM BOXC

CASE NO. 2

DOUGLAS AIRCRAFT COMPANY
LONG BEACH DIVISION
TUESDAY, JUL 31, 1979
10 X 6 MISSILE - ONE PLANE OF SYMMETRY TEST CASE

N	M	X Y Z	X Y Z	X Y Z	X Y Z	NX NY NZ	NPX NPY NPZ	Q T A
9	1	0.600000	0.600000	0.200000	0.200000	0.0	0.400000	0.2980E-07
		0.0	0.057291	0.057291	0.0	0.258819	0.028646	0.4044E+00
		-0.114583	-0.099232	-0.099232	-0.114583	-0.965926	-0.106907	0.2372E-01
	2	0.600000	0.600000	0.200000	0.200000	0.0	0.400000	0.4058E-07
		0.057291	0.099232	0.099232	0.057291	0.707107	0.078262	0.4044E+00
		-0.099232	-0.057292	-0.057292	-0.099232	-0.707107	-0.078262	0.2372E-01
	3	0.600000	0.600000	0.200000	0.200000	0.0	0.400000	0.2608E-07
		0.099232	0.114583	0.114583	0.099232	0.965926	0.106907	0.4044E+00
		-0.057292	-0.000000	-0.000000	-0.057292	-0.258819	-0.028646	0.2372E-01
	4	0.600000	0.600000	0.200000	0.200000	0.0	0.400000	0.3353E-07
		0.114583	0.099232	0.099232	0.114583	0.965926	0.106907	0.4044E+00
		-0.000000	0.057291	0.057291	-0.000000	0.258819	0.028646	0.2372E-01
	5	0.600000	0.600000	0.200000	0.200000	0.0	0.400000	0.5960E-07
		0.099232	0.057292	0.057292	0.099232	0.707107	0.078262	0.4044E+00
		0.057291	0.099232	0.099232	0.057291	0.707107	0.078262	0.2372E-01
	6	0.600000	0.600000	0.200000	0.200000	0.0	0.400000	0.3725E-08
		0.057292	-0.000000	-0.000000	0.057292	0.258820	0.028646	0.4044E+00
		0.099232	0.114583	0.114583	0.099232	0.965926	0.106907	0.2373E-01
10	1	0.200000	0.200000	0.0	0.0	0.0	0.100000	0.3353E-07
		0.0	0.057291	0.057291	0.0	0.258819	0.028646	0.2096E+00
		-0.114583	-0.099232	-0.099232	-0.114583	-0.965926	-0.106907	0.1186E-01
	2	0.200000	0.200000	0.0	0.0	0.0	0.100000	0.3725E-07
		0.057291	0.099232	0.099232	0.057291	0.707107	0.078262	0.2086E+00
		-0.099232	-0.057292	-0.057292	-0.099232	-0.707107	-0.078262	0.1186E-01
	3	0.200000	0.200000	0.0	0.0	0.0	0.100000	0.3353E-07
		0.099232	0.114583	0.114583	0.099232	0.965926	0.106907	0.2086E+00
		-0.057292	-0.000000	-0.000000	-0.057292	-0.258820	-0.028646	0.1186E-01
	4	0.200000	0.200000	0.0	0.0	0.0	0.100000	0.3725E-07
		0.114583	0.099232	0.099232	0.114583	0.965926	0.106907	0.2086E+00
		-0.000000	0.057291	0.057291	-0.000000	0.258819	0.028646	0.1186E-01
	5	0.200000	0.200000	0.0	0.0	0.0	0.100000	0.6333E-07
		0.099232	0.057292	0.057292	0.099232	0.707107	0.078262	0.2086E+00
		0.057291	0.099232	0.099232	0.057291	0.707107	0.078262	0.1186E-01
	6	0.200000	0.200000	0.0	0.0	0.0	0.100000	0.0
		0.057292	-0.000000	-0.000000	0.057292	0.258820	0.028646	0.2086E+00
		0.099232	0.114583	0.114583	0.099232	0.965926	0.106907	0.1186E-01

************ ************ ************

Figure 18a. (concluded)

```
$PUTT
ALTITU= -100.000000   ,CK0=  .0           ,CK1=  .0          ,CK4=  6360.00000   ,DELO2=  .625000149E-02,DELTT=  .124999993E-01,
DIVANG=  .0           ,DPIT=  .0          ,DNSCH=  .500000000  ,DYAW=  .0       ,DZ7=  .0        ,D2REF=
  .222200C06   ,FACTOR=  .0        ,FCA= -6.56000042   ,FG=  .0        ,FTORM=  .0        ,GAIN1=  .0
GAIN2=  .0           ,GEFFF=  32.1739960    ,HELIC=  1.00000000   ,INPRO=       0,INPUTO=        1,INTOPT=          1,ITUMR=
     1,JET=           0,N=          25,NN=           1,PHIZD=  .0       ,PITMAL=  .0       ,PSIZD=  .0
DELNCH=  .0           ,RAMP=  .0          ,REF=  20902704.0   ,ROTRAD=  22.0000000   ,SCARF=  .218999991F-02,SPNRAT=
  .0        ,SUSREF=  1.55099964    ,SUSON=  .0      ,TFINAL=  1.59200001    ,THIZD=  .0       ,TIME=
  .220000076E-01,TLL=  .920000076E-01,TPLOT=  .249999985E-01,TPRINT=  .249999985E-01,TROT=  .920000076E-01,VINIT=  .0
WCF=  .0             ,WDF=  .0          ,XINDOT=  .0        ,XLENG=  4.39999962   ,XMASSO=  .617269993   ,XMAX=
  .0        ,XMIN=  .498999991F-01,XMV=  109.000000   ,XTAR=  13000.0000   ,YAWMAL=  .0        ,YINDOT=  .0
YJET=  .0            ,YTAR=  .0          ,ZINDOT=  .0        ,ZJET=  .0        ,ZLL=  .0        ,ZLM=  .0
ZIN=  .0             ,ZTAR=  .0          ,DXLN=  3.00000000   ,DYLN=  .0        ,DZLN=  7.00000000   ,TI=  .220000029
$END
```

```
CASE   1

6-D TEST TRAJECTORY FOR LANCER

STAGE   1

HELICOPTER DIVE ANGLE =     0.0  DEGREES
HELICOPTER ATTITUDE =  0.0  DEGREES
LAUNCHER OF =     0.0  MILS
INDICATED AIRSPEED =    0.0  KNOTS
INITIAL ROCKET WEIGHT = 19.86 POUNDS
```

Figure 18b. Trajectory output data for test case.

```
6-D  TRAJECTORY MARCH 7,     1973                                                          PAGE    1

TIME  = 0.99999998E-01   XXX   = 0.0              YYY   = 0.0              ZZZ   =-0.10000000E+03   VEL P = 0.10949832E+03
MASS  = 0.61726999E+01   XDOT  = 0.10900000E+03   YDOT  = 0.0              ZDOT  = 0.0              MACH  = 0.98110497E-01
THRST = 0.74700000E+03   PPP   = 0.0              QQQ   = 0.0              RRR   = 0.0              DYNPR = 0.14209353E+02
DIST  = 0.13000383E+05   PDOT  = 0.15340730E+05   QDOT  = 0.19213139E+03   RDOT  =-0.17941177E+02   ALFT  = 0.25752264E+00
CG    = 0.26264372E+01   UUU   = 0.10900000E+03   VVV   = 0.0              WWW   = 0.0              RHO   = 0.23702250E-02
CP    = 0.12951715E+01   UDOT  = 0.12996843E+04   VDOT  = 0.32310903E+00   WDOT  = 0.35633850E+02   ALFTD = 0.15788568E+02
PMOMA = 0.0              ALF D =-0.15723565E+02   BET D =-0.15059214E+01   ETA D = 0.15789568E+02   FORSU = 0.12096843E+04
QMOMA = 0.22647480E+01   THETA = 0.0              PHI D = 0.0              PSI D = 0.0              FORSV = 0.32310903E+00
RMOMA =-0.26752946E+00   RELVX = 0.11263278E+03   RELVY =-0.27700357E+01   RELVZ = 0.29664169E+02   FORSW = 0.34601622E+01
PMOMG = 0.16353291E+01   WINDX = 0.36327820E+01   WINDY = 0.27700357E+01   WINDZ = 0.29664169E+02   MDOT  = 0.11745280E+00
QMOMG = 0.0              RMOMG = 0.0              CA    = 0.50846279E+00   CN    = 0.49864460E+01   CN    =-0.45629507E+00
CNALP = 0.36590099E+01   RETI  =-0.26293294E-01   BANK  =-0.30484829E+01   CL    = 0.0              CMO   =-0.91927856E+03
 TIME FOR   1 CALLS TO HELVEL  CPU  0.2825  I/O  0.6800, AND FOR  1 DOWNWASH CALCULATIONS   CPU  0.2842  I/O  0.5800
PERTURBATION FORCES AND MOMENTS -0.00140336 -0.00403354  0.00152926  0.00026079 -0.00185832
UNIFORM FLOW FORCES AND MOMENTS  0.00052017  0.01194491  0.09453580  0.02451294 -0.00249250
          THE TOTAL TIME FOR THIS FLOW WAS   0.30933 SECONDS
PERTURBATION FORCES AND MOMENTS -0.00142872 -0.00400646  0.00150169  0.00032739 -0.00186698
UNIFORM FLOW FORCES AND MOMENTS  0.00052396  0.01274955  0.09404492  0.02419034 -0.00266910
          THE TOTAL TIME FOR THIS FLOW WAS   0.36508 SECONDS
PERTURBATION FORCES AND MOMENTS -0.00199757 -0.00236184 -0.00036334  0.00222696 -0.00092616
UNIFORM FLOW FORCES AND MOMENTS  0.00041358  0.01125459  0.08759106  0.02153407 -0.00213708
          THE TOTAL TIME FOR THIS FLOW WAS   0.35725 SECONDS
PERTURBATION FORCES AND MOMENTS -0.00199755 -0.00236490 -0.00036157  0.00222677 -0.00092788
UNIFORM FLOW FORCES AND MOMENTS  0.00041368  0.01126162  0.08798921  0.02153264 -0.00213857
          THE TOTAL TIME FOR THIS FLOW WAS   0.36683 SECONDS
PERTURBATION FORCES AND MOMENTS -0.00204891 -0.00108151 -0.00097827  0.00185725 -0.00034884
UNIFORM FLOW FORCES AND MOMENTS  0.00031478  0.01126076  0.08123243  0.01842461 -0.00192995
          THE TOTAL TIME FOR THIS FLOW WAS   0.36983 SECONDS
PERTURBATION FORCES AND MOMENTS -0.00204719 -0.00106008 -0.00101112  0.00190136 -0.00035183
UNIFORM FLOW FORCES AND MOMENTS  0.00021693  0.01195441  0.08067268  0.01808197 -0.00205890
          THE TOTAL TIME FOR THIS FLOW WAS   0.35925 SECONDS

TIME  = 0.11699986E+00   XXX   = 0.31026167E+01   YYY   = 0.17569163E-03   ZZZ   =-0.99988785E+02   VEL P = 0.13104504E+03
MASS  = 0.61526772E+01   XDOT  = 0.13172343E+03   YDOT  = 0.11394576E-01   ZDOT  = 0.67262089E+00   MACH  = 0.11741638E+00
THRST = 0.74700000E+03   PPP   = 0.38254023E+03   QQQ   = 0.54540968E+01   RRR   =-0.10385372E+01   DYNPR = 0.20351685E+02
DIST  = 0.12927277E+05   PDOT  = 0.15157250E+05   QDOT  = 0.22990633E+03   RDOT  =-0.55961456E+02   ALFT  = 0.22558886E+00
CG    = 0.26214745E+01   UUU   = 0.13230333E+03   VVV   = 0.11535242E+00   WWW   = 0.10464783E+01   RHO   = 0.23702250E-02
CP    = 0.12351715E+01   UDOT  = 0.12136611E+04   VDOT  = 0.77591848E+01   WDOT  = 0.45200424E+02   ALFTD = 0.13744426E+02
PMOMA =-0.24799513E-01   ALF D =-0.13589976E+02   BET D =-0.21340160E+01   ETA D = 0.13744423E+02   FORSU = 0.12137385E+04
QMOMA = 0.34465916E+01   THETA = 0.66456510E-01   PHI D = 0.47682705E+01   PSI D =-0.34049553E-02   FORSV = 0.60922701E+00
RMOMA =-0.53545123E+00   RELVX = 0.13617690E+03   RELVY =-0.31683693E+01   RELVZ = 0.31251973E+02   FORSW = 0.41299336E+01
PMOMG = 0.16352291E+01   WINDX = 0.44533377E+01   WINDY = 0.21802645E+01   WINDZ = 0.31924545E+02   MDOT  = 0.11745280E+00
QMOMG = 0.0              RMOMG = 0.0              CA    = 0.53329881E+00   CN    = 0.40858927E+01   CN    =-0.62914938E+00
CNALP = 0.30930943E+01   RETI  =-0.24844833E-01   BANK  =-0.29886522E+01   CL    =-0.29534105E-01   CMO   =-0.91927856E+03
 TIME FOR  61 CALLS TO HELVEL  CPU  6.3769  I/O  0.6800, AND FOR 61 DOWNWASH CALCULATIONS   CPU  6.4227  I/O  0.6800
```

Figure 18b. (continued)

```
6-D  TRAJECTORY MARCH 7,     1973                                                                    PAGE    10

TIME = 0.14044580E+01    XXX  = 0.12329060E+04    YYY  =-0.70962458E+01    ZZZ  =-0.67479156E+02    VEL R= 0.17543777E+04
MASS = 0.46311563E+00    XDOT = 0.17530735E+04    YDOT =-0.10439167E+02    ZDOT = 0.66800949E+02    MACH = 0.15717497E+01
THRST= 0.74700000E+03    PPP  = 0.14900049E+04    QQQ  = 0.88086015E+00    RRR  = 0.49665779E+00    DYNPR= 0.36509907E+04
DIST = 0.11767290E+05    PDOT =-0.11708818E+04    QDOT =-0.48274796E+02    RDOT = 0.35641586E+02    ALFI =-0.38086619E-01
CG   = 0.28800978E+01    UUU  = 0.17543779E+04    VVV  = 0.42619830E+00    WWW  = 0.41561049E+00    RHO  = 0.23724362E-02
CP   = 0.10375473E+01    UDOT = 0.11598472E+04    VDOT = 0.17214828E+02    WDOT = 0.38129730E+02    ALFTO= 0.19441597E-01
PHOMA=-0.17324320E+01    ALF D= 0.13573315E-01    BET D= 0.13919100E-01    ETA D= 0.19441582E-01    FORSU= 0.11586377E+04
QHOMA=-0.69371239E+00    THETA=-0.21739393E+01    PHI D= 0.32887981E+04    PSI D=-0.44884115E+00    FORSV=-0.81433052E+00
RHOMA= 0.66239204E+00    RELVX= 0.17530735E+04    RELVY=-0.10439167E+02    RELVZ=-0.66800949E+02    FORSW=-0.79410136E+00
PHOMG= 0.16359291E+01    WINDX= 0.0               WINDY= 0.0               WINDZ= 0.0               MDOT = 0.11745280E+00
QHOMG= 0.0               RHOMG= 0.0               CA   = 0.13968515E+01    CM   =-0.46052113E-02    CN   = 0.44006109E-02
CNALP= 0.34968879E-02    BETI =-0.13221181E-04    BANK = 0.79797441E+00    CL   =-0.11501089E-01    CMQ  =-0.43993975E+03
 TIME FOR 344  CALLS TO HELVEL  CPU 32.5548   I/O  0.6800, AND FOR781  DOWNWASH CALCULATIONS  CPU 33.0065  I/O  0.6800

TIME = 0.14410546E+01    XXX  = 0.12994580E+04    YYY  =-0.74920597E+01    ZZZ  =-0.64921677E+02    VEL R= 0.17977095E+04
MASS = 0.45871127E+00    XDOT = 0.17962291E+04    YDOT =-0.10667016E+02    ZDOT = 0.69611908E+02    MACH = 0.16105709E+01
THRST= 0.74700000E+03    PPP  = 0.14476904E+04    QQQ  =-0.25590323E+00    RRR  = 0.27210817E+01    DYNPR= 0.38335710E+04
DIST = 0.11707223E+05    PDOT =-0.10875286E+04    QDOT = 0.22407745E+02    RDOT =-0.15970192E+01    ALFI =-0.38732935E-01
CG   = 0.28834529E+01    UUU  = 0.17977095E+04    VVV  = 0.13183355E-02    WWW  = 0.27975661E+00    RHO  = 0.23724362E-02
CP   = 0.11117716E+01    UDOT = 0.11511370E+04    VDOT =-0.46583527E+02    WDOT =-0.13834285E+02    ALFTO= 0.89163668E-02
PHOMA=-0.17243573E+01    ALF D= 0.89162737E-02    BET D= 0.42017375E-04    ETA D= 0.99163669E-02    FORSU= 0.11498911E+04
QHOMA=-0.43712378E+00    THETA=-0.22324905E+01    PHI D= 0.33438679E+04    PSI D=-0.44322395E+00    FORSV=-0.25636693E-02
RHOMA=-0.90483129E-01    RELVX= 0.17963291E+04    RELVY=-0.10667016E+02    RELVZ=-0.69611908E+02    FORSW=-0.54402238E+00
PHOMG= 0.16359291E+01    WINDX= 0.0               WINDY= 0.0               WINDZ= 0.0               MDOT = 0.11745280E+00
QHOMG= 0.0               RHOMG= 0.0               CA   = 0.13879538E+01    CM   =-0.27636425E-02    CN   =-0.57206466E-03
CNALP= 0.15777512E-02    BETI =-0.15125747E-03    BANK = 0.47123991E-02    CL   =-0.10905124E-01    CMQ  =-0.42178027E+03
 TIME FOR 344  CALLS TO HELVEL  CPU 32.5548   I/O  0.6800, AND FOR793  DOWNWASH CALCULATIONS  CPU 33.0106  I/O  0.6800

TIME = 0.14794512E+01    XXX  = 0.13676257E+04    YYY  =-0.73969822E+01    ZZZ  =-0.62256348E+02    VEL R= 0.18407029E+04
MASS = 0.45437690E+00    XDOT = 0.18392395E+04    YDOT =-0.10937177E+02    ZDOT = 0.72546478E+02    MACH = 0.16489964E+01
THRST= 0.74700000E+03    PPP  = 0.14081326E+04    QQQ  =-0.12752432E+00    RRR  =-0.23296340E+00    DYNPR= 0.40210220E+04
DIST = 0.11632539E+05    PDOT =-0.10223406E+04    QDOT =-0.23374420E+02    RDOT =-0.68017532E+02    ALFI =-0.39423302E-01
CG   = 0.29060037E+01    UUU  = 0.18407029E+04    VVV  =-0.50445217E+00    WWW  = 0.12161607E+00    RHO  = 0.23735540E-02
CP   = 0.11352773E+01    UDOT = 0.11419029E+04    VDOT = 0.27753820E+02    WDOT =-0.20543015E+02    ALFTO= 0.16151994E-01
PHOMA=-0.17136524E+01    ALF D= 0.37855569E-02    BET D=-0.15702121E-01    ETA D= 0.16151994E-01    FORSU= 0.11406265E+04
QHOMA=-0.13924254E+00    THETA=-0.22702198E+01    PHI D= 0.33974070E+04    PSI D=-0.46858078E+00    FORSV= 0.99809533E+00
RHOMA=-0.74316604E+00    RELVX= 0.18392395E+04    RELVY=-0.10937177E+02    RELVZ=-0.72546478E+02    FORSW=-0.24062669E+00
PHOMG= 0.16359291E+01    WINDX= 0.0               WINDY= 0.0               WINDZ= 0.0               MDOT = 0.11745280E+00
QHOMG= 0.0               RHOMG= 0.0               CA   = 0.13791475E+01    CM   =-0.11406785E-02    CN   =-0.47808886E-02
CNALP= 0.28114726E-02    BETI = 0.22764107E-03    BANK =-0.13342247E+01    CL   =-0.10759392E-01    CMQ  =-0.40375635E+03
 TIME FOR 344  CALLS TO HELVEL  CPU 32.5548   I/O  0.6800, AND FOR805  DOWNWASH CALCULATIONS  CPU 33.0153  I/O  0.6800

TIME = 0.15169477E+01    XXX  = 0.14373960E+04    YYY  =-0.33121109E+01    ZZZ  =-0.59481796E+02    VEL R= 0.18833501E+04
MASS = 0.44990253E+00    XDOT = 0.18318057E+04    YDOT =-0.11192759E+02    ZDOT = 0.75411896E+02    MACH = 0.16972025E+01
THRST= 0.74700000E+03    PPP  = 0.13712019E+04    QQQ  = 0.12704601E+01    RRR  =-0.90654278E+00    DYNPR= 0.42095039E+04
DIST = 0.11562759E+05    PDOT =-0.95074023E+03    QDOT = 0.20483231E+02    RDOT =-0.16503525E+02    ALFI =-0.40052794E-01
CG   = 0.29135637E+01    UUU  = 0.18833502E+04    VVV  = 0.76650798E-01    WWW  =-0.66715854E+00    RHO  = 0.23735540E-02
CP   = 0.11599903E+01    UDOT = 0.11326240E+04    VDOT = 0.12333351E+00    WDOT = 0.12116592E+02    ALFTO= 0.20429973E-01
PHOMA=-0.17122535E+01    ALF D=-0.20296451E-01    BET D= 0.23313899E-02    ETA D= 0.20429961E-01    FORSU= 0.11313342E+04
QHOMA= 0.10167847E+01    THETA=-0.22302275E+01    PHI D= 0.34495098E+04    PSI D=-0.44664159E+00    FORSV=-0.15410846E+00
RHOMA= 0.15115625E+00    RELVX= 0.18318057E+04    RELVY=-0.11192759E+02    RELVZ=-0.75411896E+02    FORSW= 0.13413391E+01
PHOMG= 0.16359291E+01    WINDX= 0.0               WINDY= 0.0               WINDZ= 0.0               MDOT = 0.11745280E+00
QHOMG= 0.0               RHOMG= 0.0               CA   = 0.13703209E+01    CM   = 0.53543570E-02    CN   = 0.87031443E-03
CNALP= 0.34974760E-02    BETI =-0.20991125E-03    BANK = 0.30272026E+01    CL   =-0.98592713E-02    CMQ  =-0.38583545E+03
 TIME FOR 344  CALLS TO HELVEL  CPU 32.5548   I/O  0.6800, AND FOR817  DOWNWASH CALCULATIONS  CPU 33.0198  I/O  0.6800
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Figure 18b. (continued)

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6-D  TRAJECTORY MARCH 7,    197                                       PAGE   11

TIME = 0.15544443E+01  XXX  = 0.15037559E+04  YYY  =-0.87364187E+01  ZZZ  =-0.56599762E+02  VEL R= 0.19256453E+04
MASS = 0.44549817E+00  XDOT = 0.19240171E+04  YDOT =-0.11439672E+02  ZDOT = 0.78314362E+02  MACH = 0.17250919E+01
THRST= 0.0             PPP  = 0.13367209E+04  QQQ  = 0.86682838E+00  RRR  =-0.85242934E+00  DYNPP= 0.44006953E+04
DIST = 0.11491383E+05  PDOT =-0.21398570E+05  QDOT =-0.65999619E+02  RDOT = 0.47061066E+02  ALFI =-0.40691109E-01
CG   = 0.29199609E+01  UUU  = 0.19256455E+04  VVV  = 0.44871408E+00  WWW  = 0.30352718E+00  RHO  = 0.23735540E-02
CP   = 0.11837225E+01  UDOT =-0.55367773E+03  VDOT = 0.37073250E+01  WDOT = 0.10052307E+02  ALFTO= 0.16118698E-01
PMOMA=-0.17067842E+01  ALF D= 0.90311654E-02  BET D= 0.13351064E-01  ETA D= 0.16118699E-01  FORSU=-0.55498120E+03
QMOMA=-0.50634492E+00  THETA=-0.23565292E+01  PHI D= 0.35002756E+04  PSI D=-0.46791655E+00  FORSV=-0.91604161E+00
RMOMA= 0.73563319E+00  RELVX= 0.19240171E+04  RELVY=-0.11439672E+02  RELVZ=-0.78314362E+02  FORSW=-0.61964571E+00
PMOMG= 0.0             WINDX= 0.0             WINDY= 0.0             WINDZ= 0.0             MDOT = 0.0
QMOMG= 0.0             RMOMG= 0.0             CA   = 0.13617077E+01  CM   =-0.27914809E-02  CN   = 0.40515475E-02
CNALP= 0.27135347E-02  BETI = 0.11600283E-03  BANK = 0.97605914E+00  CL   =-0.94002299E-02  CMQ  =-0.36806299E+03
 TIME FOR 344  CALLS TO HELVEL  CPU 32.5548  I/O  0.6800, AND FOR828  DOWNWASH CALCULATIONS  CPU 33.0237  I/O  0.6800

TIME = 0.15544443E+01  XXX  = 0.15087559E+04  YYY  =-0.87360992E+01  ZZZ  =-0.56559625E+02  VEL R= 0.19221519E+04
MASS = 0.44574285E+00  XDOT = 0.19205269E+04  YDOT =-0.11406298E+02  ZDOT = 0.78184967E+02  MACH = 0.17219629E+01
THRST= 0.0             PPP  = 0.12939972E+04  QQQ  = 0.87379197E+00  RRR  =-0.89333487E+00  DYNPP= 0.43847422E+04
DIST = 0.11491383E+05  PDOT =-0.22677086E+05  QDOT =-0.70994995E+02  RDOT = 0.50880081E+02  ALFI =-0.40687703E-01
CG   = 0.29198603E+01  UUU  = 0.19221521E+04  VVV  = 0.46521038E+00  WWW  = 0.33649957E+00  RHO  = 0.23735540E-02
CP   = 0.11817675E+01  UDOT =-0.55165356E+03  VDOT = 0.54692774E+01  WDOT = 0.90073862E+01  ALFTO= 0.17114438E-01
PMOMA=-0.16492367E+01  ALF D= 0.10036422E-01  BET D= 0.13867054E-01  ETA D= 0.17114438E-01  FORSU=-0.55295579E+03
QMOMA=-0.55844772E+00  THETA=-0.23574076E+01  PHI D= 0.35002756E+04  PSI D=-0.46843761E+00  FORSV=-0.94879812E+00
RMOMA= 0.76356077E+00  RELVX= 0.19205269E+04  RELVY=-0.11406298E+02  RELVZ=-0.78184967E+02  FORSW=-0.68629241E+00
PMOMG= 0.0             WINDX= 0.0             WINDY= 0.0             WINDZ= 0.0             MDOT = 0.0
QMOMG= 0.0             RMOMG= 0.0             CA   = 0.13624249E+01  CM   =-0.30868773E-02  CN   = 0.42206608E-02
CNALP= 0.29251877E-02  BETI = 0.13167162E-03  BANK = 0.94458485E+00  CL   =-0.91163293E-02  CMQ  =-0.36953076E+03
 TIME FOR 344  CALLS TO HELVEL  CPU 32.5548  I/O  0.6800, AND FOR829  DOWNWASH CALCULATIONS  CPU 33.0241  I/O  0.6800

TIME = 0.15919409E+01  XXX  = 0.15802892E+04  YYY  =-0.91618643E+01  ZZZ  =-0.53660446E+02  VEL P= 0.19016545E+04
MASS = 0.44574235E+00  XDOT = 0.18999976E+04  YDOT =-0.11299660E+02  ZDOT = 0.78557816E+02  MACH = 0.17035999E+01
THRST= 0.0             PPP  = 0.71300171E+03  QQQ  =-0.76172441E+00  RRR  =-0.59362253E-01  DYNPR= 0.42917266E+04
DIST = 0.11419738E+05  PDOT =-0.11271738E+05  QDOT =-0.17930527E+02  RDOT =-0.49138397E+02  ALFI =-0.41322734E-01
CG   = 0.29196603E+01  UUU  = 0.19016548E+04  VVV  =-0.39364159E+00  WWW  = 0.13435614E+00  RHO  = 0.23735540E-02
CP   = 0.11702032E+01  UDOT =-0.54157666E+03  VDOT =-0.25336212E+02  WDOT =-0.84293785E+01  ALFTO= 0.12674671E-01
PMOMA=-0.89905131E+00  ALF D= 0.40480718E-02  BET D=-0.12010843E-01  ETA D= 0.12674667E-01  FORSU=-0.54289844E+03
QMOMA=-0.18856306E+00  THETA=-0.23657408E+01  PHI D= 0.35368103E+04  PSI D=-0.46244347E+00  FORSV= 0.81094396E+00
RMOMA=-0.63056392E+00  RELVX= 0.18999976E+04  RELVY=-0.11299660E+02  RELVZ=-0.78557816E+02  FORSW=-0.27331710E+00
PMOMG= 0.0             WINDX= 0.0             WINDY= 0.0             WINDZ= 0.0             MDOT = 0.0
QMOMG= 0.0             RMOMG= 0.0             CA   = 0.13666334E+01  CM   =-0.10649201E-02  CN   =-0.35610776E-02
CNALP= 0.21542071E-02  BETI =-0.31495583E-04  BANK =-0.12457170E+01  CL   =-0.50773062E-02  CMQ  =-0.37814404E+03
 TIME FOR 344  CALLS TO HELVEL  CPU 32.5548  I/O  0.6800, AND FOR841  DOWNWASH CALCULATIONS  CPU 33.0284  I/O  0.6800
TIME EXCEEDS MAX.RUN NEXT CASE

TIME = 0.15921902E+01  XXX  = 0.15922639E+04  YYY  =-0.92324867E+01  ZZZ  =-0.53169449E+02  VEL R= 0.19016545E+04
MASS = 0.44574235E+00  XDOT = 0.18999976E+04  YDOT =-0.11299669E+02  ZDOT = 0.78557816E+02  MACH = 0.17035999E+01
THRST= 0.0             PPP  = 0.54255347E+03  QQQ  =-0.97379009E+00  RRR  =-0.35922712E+00  DYNPP= 0.42917266E+04
DIST = 0.11407859E+05  PDOT =-0.11271738E+05  QDOT =-0.17930527E+02  RDOT =-0.49139397E+02  ALFI =-0.41322734E-01
CG   = 0.29129603E+01  UUU  = 0.18982698E+04  VVV  =-0.55699289E+00  WWW  = 0.81672549E-01  RHO  = 0.23735540E-02
CP   = 0.11702032E+01  UDOT =-0.54157666E+03  VDOT =-0.25336212E+02  WDOT =-0.84293785E+01  ALFTO= 0.12674671E-01
PMOMA=-0.89905131E+00  ALF D= 0.40480718E-02  BET D=-0.12010843E-01  ETA D= 0.12674667E-01  FORSU=-0.54289844E+03
QMOMA=-0.18856806E+00  THETA=-0.23582137E+01  PHI D= 0.35412654E+04  PSI D=-0.45835537E+00  FORSV= 0.81094396E+00
RMOMA=-0.63056892E+00  RELVX= 0.18999976E+04  RELVY=-0.11299660E+02  RELVZ=-0.78557816E+02  FORSW=-0.27331710E+00
PMOMG= 0.0             WINDX= 0.0             WINDY= 0.0             WINDZ= 0.0             MDOT = 0.0
QMOMG= 0.0             RMOMG= 0.0             CA   = 0.13666334E+01  CM   =-0.10649201E-02  CN   =-0.35610776E-02
CNALP= 0.21542071E-02  BETI =-0.31495583E-04  BANK =-0.12457170E+01  CL   =-0.50773062E-02  CMQ  =-0.37814404E+03
```

Figure 18b. (concluded)